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16. ABSTRACT

This report presents an evaluation of the in-orbit performance of the Instrumentation and Communications Systems. Performance is compared with functional requirements and the fidelity of communications.

In-orbit performance includes processing engineering, scientific, experiment, and biomedical data, implementing ground-generated commands, audio and video communication, generating rendezvous ranging information and radio frequency transmission and reception.

A brief history of the system evolution based on the functional requirements along with a physical description of the launch configuration is included as an aid to a clear understanding of the System performance.

In conclusion, the report affirms that the Instrumentation and Communication Systems satisfied all imposed requirements. Recommendations are offered which may be beneficial to future space programs.

EDITOR'S NOTE

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DEFINITION OF SYMBOLS

C	Centigrade
$^{\circ}$	Degree
f	Frequency
$\geq$	Greater than or equal to
K	Kelvin
$<$	Less than
μ	Micro
m	Milli
n	Nano (10^{-9})
Ω	Ohm
R_o	Output Resistance
τ	Time (Measured from frequency)
Δt	Delta time

NONSTANDARD ABBREVIATIONS

ACN	Ascension Island
ACS	Attitude Control System
AGC	Automatic Gain Control
ALC	Automatic Light Control (Television)
ALC	Audio Load Compensator
AM	Airlock Module
AMB	Ambient
AMP	Amplifier
AOS	Acquisition of Signal
APCS	Attitude Propulsion Control System
ASA	Amplifier Switching Assembly
ASAP	Auxiliary Storage and Playback Assembly
ATM	Apollo Telescope Mount
ATMDC	Apollo Telescope Mount Digital Computer
AVG	Average
BDA	Bermuda
BL	Bilevel
BLP	Bilevel Pulse
C&D	Control and Display
CCU	Crewman Communication Umbilical
CDR	Commander
CFM	Cubic Feet per Minute
CHAN(CH)	Channel
CKT	Circuit
CLNT	Coolant
CMD	Command
CMG	Control Moment Gyro
COCOA	Computer Oriented Communications Operational Analysis
COMM	Communications
COMPT	Compartment
CRDU	Command Relay Driver Unit
CRO	Carnarvon, Australia
CSM	Command Service Module
CTL	Control
C&W	Caution and Warning
CVPR	Control Valve-Primary B
CWU	Caution and Warning Unit
CYI	Grand Canary Island
DAS	Data Acquisition System
dB	Decibel
dBm	Decibel (referenced to 1 milliwatt)

NONSTANDARD ABBREVIATIONS (continued)

DC	Direct Current
DCS	Digital Command System
DDAS	Digital Data Acquisition System
DIG	Digital
DOY	Day of Year
DSM	Digital Select Matrix
EAR	Earphone
EIA	Electronic Industries Association
EMER	Emergency
EMI	Electromagnetic Interference
EPS	Electrical Power System
EREP	Earth Resources Experiment Package
EVA	Extravehicular Activity
EXP	Experiment
EXT	External
FM	Frequency Modulation
FMS	Food Management System
FRZR	Freezer
FS	Full Scale
FWD	Forward
GDS	Goldstone, California
GMT	Greenwich Mean Time
GSFC	Goddard Space Flight Center
GWM	Guam
HAW	Hawaii
HL	High Level
HPI	High Performance Insulation
HSK	Honeysuckle Creek, Austrailia
HTR	Heater
Hα	Hydrogen Alpha
IB	Interface Box
I&C	Instrumentation and Communication
ICOM	Intercommunication
IEEEU	Institute of Electrical and Electronic Engineers Unit
IMU	Inertial Measurement Unit
IN	Inlet
INSUL	Insulation
INT	Internal
IU	Instrument Unit
IVA	Intravehicular Activity

NONSTANDARD ABBREVIATIONS (continued)

JSC	Johnson Space Center
kbps	Kilobits per second
KSC	Kennedy Space Center
LBNP	Lower Body Negative Pressure
LCG	Liquid Cooled Garment
LHCP	Left Hand Circular Polarization
LL	Low Level
LOS	Loss of Signal
LP	Loop
MAD	Madrid, Spain
MDAC-E	McDonnell Douglas Astronautics Corp-East
M/C	Mixing Chamber
MDA	Multiple Docking Adapter
MIC	Microphone
MIL	Merritt Island, Florida
MISC	Miscellaneous
MOL	Molecular
MS	Meteoroid Shield
MSFC	Marshall Space Flight Center
MUX	Multiplexer
mVDC	Millivolt Direct Current
NASA	National Aeronautics and Space Administration
n mi	Nautical Mile
NTSC	National Television Standards Committee
OWS	Orbital Workshop
PAM	Pulse Amplitude Modulation
P/B	Playback
PCM	Pulse Code Modulation
pps	Pulses per Second
PRESS	PRESSURE
PRI	Primary
PROG	Programmer
psia	Pounds per square inch, absolute
psid	pounds per square inch, differential
psig	Pounds per square inch, gage
PTT	Push to Talk
QCM	Quartz Crystal Microbalance

NONSTANDARD ABBREVIATIONS (continued)

RASM	Remote Analog Submultiplexer
RCVR	Receiver
REF	Reference
REG	Gegulator
REV	Revolution
RF	Radio Frequency
RHCP	Right Hand Circular Polarization
RS	Refrigeration System
RTTA	Ranging Tone Transfer Assembly
SAS	Solar Array Shield
sec	Second
SEC	SECONDARY
SF	Subframe
SIA	Speaker Intercom Assembly
SL	Skylab
S/N	Serial Number
SPKR	Speaker
SPL	Sound Pressure Level
sps	Samples per second
STDN	Spaceflight Tracking Data Network
STOR	Storage
STS	Structure Transition Section
STU	Skylab Test Unit
SWS	Saturn Workshop
T/C	Thermal Capacitor
TCS	Thermal Control System
TEMP	Temperature
TEX	Corpus Christi, Texas
TM	Telemetry
TRA	Tape Recorder Amplifier
TRS	Time Reference System
T/S	Tension Strap
TV	Television
TVIS	Television Input Section
UHF	Ultra High Frequency
UV	Ultra-Violet
V	Volts
VABD	Van Allen Belt Dosimeter
VAN	U S Naval Ship Vanguard
VCS	Ventilation Control System
VHF	Very High Frequency
VIT	Vertical Interval Test
VTR	Video Tape Recorder
VTS	Viewfinder Tracking System

NONSTANDARD ABBREVIATIONS (continued)

WDRM	Wardroom
WLC	White Light Chronograph
WMC	Waste Management Compartment
XMIT	Transmit
XMTR	Transmitter
XUV	Extreme Ultraviolet

SECTION I. SUMMARY

The Skylab Instrumentation and Communication (I&C) System launch configuration was dictated by mission objectives. The progress of the system development was regulated by NASA panel meetings, design reviews, certification reviews and flight readiness reviews. The seven systems that made up the I&C System were:

- Apollo Telescope Mount (ATM) Data
- ATM Command
- Airlock Module (AM) Data
- AM Command
- Skylab (SL) Audio
- SL Television
- SL Rendezvous Ranging

The intricate design and operation of the I&C System required the development and use of functional test beds and support documentation to maintain system integrity during the mission. The test beds included an ATM I&C breadboard at Marshall Space Flight Center (MSFC), a complete I&C System test unit at St. Louis, a system simulator at Johnson Space Center (JSC) and a computer program for radio frequency (RF) tracking data at Denver. The documentation included functional flow diagrams, malfunction procedures, contingency analyses and crew check lists.

Capability and reliability of the system were verified by premission testing which was conducted at the component, black box, subsystem, system and combined system levels. Results from this activity required some hardware modifications and documentation changes as well as identifying possible system weaknesses to be monitored during the mission. The recognition of possible in-orbit problems produced contingency procedures for use as required during the mission. During the mission, anomalies occurred that required additional ground testing using the I&C test beds and in some cases back-up crew participation to provide work-around procedures and contingency hardware to be implemented by the flight crew.

Downlinked instrumentation data provided a near-continuous monitor of the status of the Skylab and the crews. Communication was maintained with the crew via downlinked audio and video and uplinked audio and teleprinter messages. The vehicle systems were operated by ground commands as much as possible leaving the crew free to perform experiments and other program-related duties. The data and command systems operated continually during the manned and unmanned phases of the mission while the audio, television and ranging systems were required only during the manned phases of the mission.

Performance of the I&C System was adequate to support the objectives of the Skylab Mission even though the system suffered some anomalies. The system redundancy and utilization of onboard spares, in most cases, minimized the effect of the anomalous hardware. The most significant problems were the loss of a transmitter and multiplexers in the AM Data System, squeal in the Audio System and loss of cameras and a monitor in the Television System. Evaluation of the I&C System performance has produced significant and valuable engineering knowledge that can be applied to future space programs.

SECTION II. INTRODUCTION

The Astrionics Laboratory of the Marshall Space Flight Center prepared this report, which evaluates the performance of the Instrumentation and Communication Systems for the Skylab mission including the two-way voice communication, telemetry downlink of the engineering and scientific data, television, and uplink of the commands to Skylab.

Skylab, a continuation of the nation's manned space flight programs, used experience and equipment from previous space activities. It was designed to operate in low Earth orbit, sufficiently above the atmosphere to avoid interference, and low enough to accommodate a maximum payload. The Skylab was successfully launched on May 14, 1973, and circled the Earth every 93 minutes at approximately 234 n mi altitude with its orbit inclined 50 deg. from the equator. It was manned by three different crews for 171 of the 271 days covered by this report. Its purpose was to advance the technology for accommodation of men and equipment in space for extended periods, record earth resources and solar astronomy data, and explore other modes of space utilization. Man's response, man/machine relations, long-duration operations, and other experimental investigations were incorporated in a selected balance of program objectives.

This report is limited primarily to the Instrumentation and Communication Systems' performance during the Skylab mission. It encompasses an evaluation of the systems' performance and includes information that may be used as a guide for potential designers and users of space stations. Some of the realities to be encountered are summarized and attention is directed to the indicated references for more specific details or other aspects of the program.

The Instrumentation and Communication Systems consist of: the Skylab Instrument Data systems that collect and telemeter data to the ground sites from 2060 separate measurements; the Communication System providing voice communication within Skylab and with the ground; the Television System providing video data to the ground; the Command Systems for ground control; the Rendezvous and Ranging Systems; and other related equipment.

The Skylab mission began with the launch of Skylab on day of year (DOY) 134 (May 14, 1973) and was terminated after splashdown of SL-4 on DOY 39 (February 8, 1974) for a total period of operation of 271 days. Manned operations covered 171 days of this period and included three different crews of three men each. The successive times of habitation were 28, 59, and 84 days. The overall mission profile is shown in Figure 2-1 and a detailed time reference is shown in Table II-1. The primary time in the report is in DOY and using GMT reference.

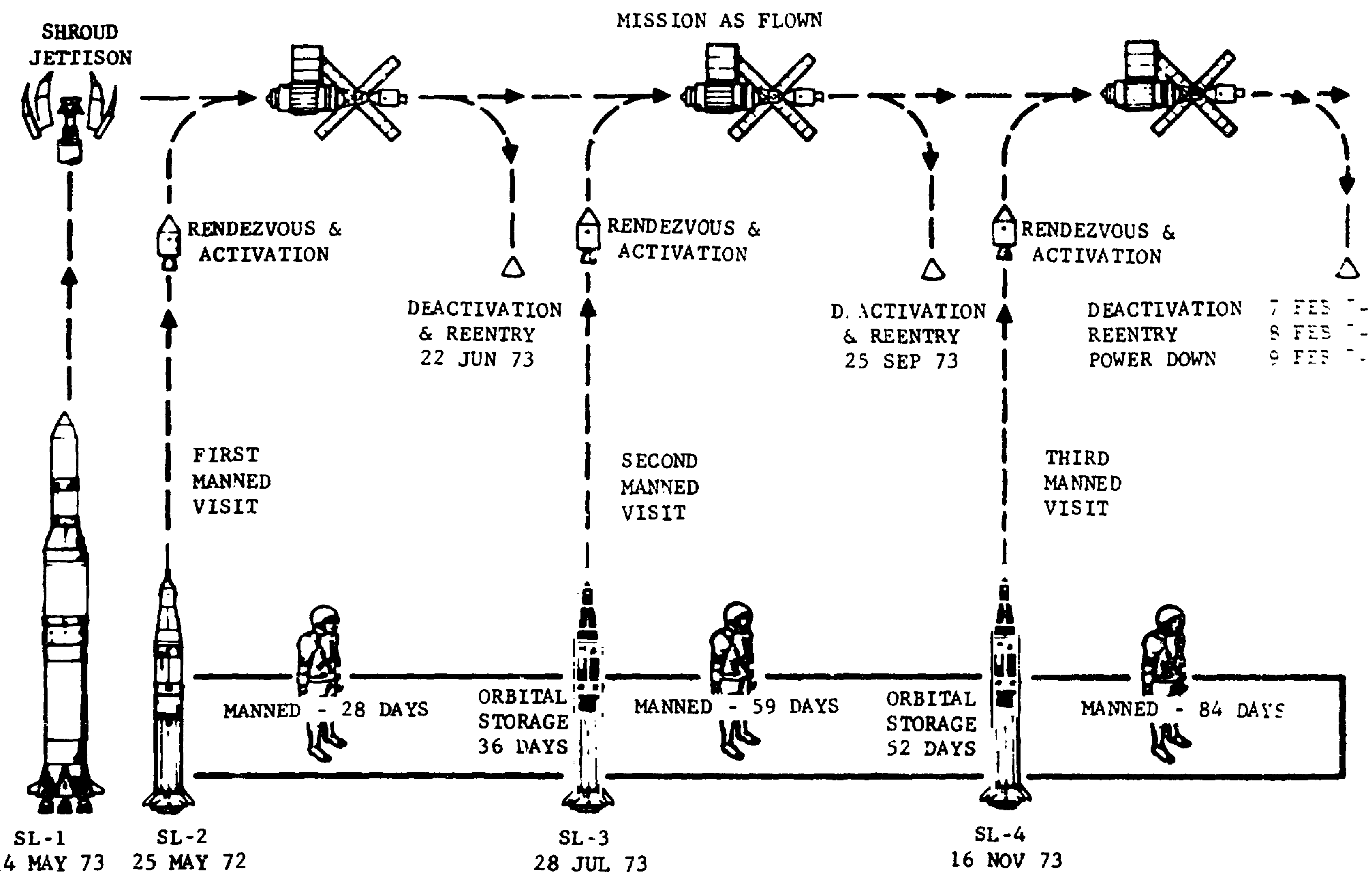


FIGURE 2-1. SKYLAB MISSION PROFILE

Table II-1. Skylab Mission Day Time Reference (Sheet 1 of 2)

DATE (1973)	DOY	MISSION PHASE	DATE (1973)	DOY	MISSION PHASE	DATE (1973)	DOY	MISSION PHASE	DATE (1973)	DOY	MISSION PHASE
5-14	134	FIRST UNMANNED PERIOD	6-17	168	24	7-21	202	SECOND UNMANNED PERIOD	8-24	236	SECOND MANNED PERIOD MISSION DAYS 28
5-15	135		6-18	169	25	7-22	203		8-25	237	29
5-1[illegible]	136		6-19	170	26	7-23	204		8-26	238	30
5-17	137		6-20	171	27	7-24	205		8-27	239	31
5-18	138		6-21	172	28	7-25	206		8-28	240	32
5-19	139		6-22	173	29	7-26	207		8-29	241	33
5-20	140		6-23	174	SECOND UNMANNED PERIOD	7-27	208		8-30	242	34
5-21	141		6-24	175		7-28	209	SECOND MANNED PERIOD MISSION DAYS 1	8-31	243	35
5-22	142		6-25	176		7-29	210	2	9-01	244	36
5-23	143		6-26	177		7-30	211	3	9-02	245	37
5-24	144		6-27	178		7-31	212	4	9-03	246	38
5-25	145	FIRST MANNED PERIOD MISSION DAYS 1	6-28	179		8-01	213	5	9-04	247	39
5-26	146	2	6-29	180		8-02	214	6	9-05	248	40
5-27	147	3	6-30	181		8-03	215	7	9-06	249	41
5-28	148	4	7-01	182		8-04	216	8	9-07	250	42
5-29	149	5	7-02	183		8-05	217	9	9-08	251	43
5-30	150	6	7-03	184		8-06	218	10	9-09	252	44
5-31	151	7	7-04	185		8-07	219	11	9-10	253	45
6-01	152	8	7-05	186		8-08	220	12	9-11	254	46
6-02	153	9	7-06	187		8-09	221	13	9-12	255	47
6-03	154	10	7-07	188		8-10	222	14	9-13	256	48
6-04	155	11	7-08	189		8-11	223	15	9-14	257	49
6-05	156	12	7-09	190		8-12	224	16	9-15	258	50
6-06	157	13	7-10	191		8-13	225	17	9-16	259	51
6-07	158	14	7-11	192		8-14	226	18	9-17	260	52
6-08	159	15	7-12	193		8-15	227	19	9-18	261	53
6-09	160	16	7-13	194		8-16	228	20	9-19	262	54
6-10	161	17	7-14	195		8-17	229	21	9-20	263	55
6-11	162	18	7-15	196		8-18	230	22	9-21	264	56
6-12	163	19	7-16	197		8-19	231	23	9-22	265	57
6-13	164	20	7-17	198		8-20	232	24	9-23	266	58
6-14	165	21	7-18	199		8-21	233	25	9-24	267	59
6-15	166	22	7-19	200		8-22	234	26	9-25	268	60
6-16	167	23	7-20	201		8-23	235	27	9-26	269	

Table II-1. (Continued) (Sheet 2 of 2)

DATE (1973)	DOY	MISSION PHASE	DATE (1973)	DOY	MISSION PHASE	DATE (73/74)	DOY	MISSION PHASE	DATE (1974)	DOY	MISSION PHASE
9-27	270	THIRD UNMANNED PERIOD	10-31	304	THIRD MANNED PERIOD MISSION DAYS	12-04	338	THIRD MANNED PERIOD MISSION DAYS 19	1-06	6	THIRD MANNED PERIOD MISSION DAYS 52
9-28	271		11-01	305		12-05	339	20	1-07	7	53
9-29	272		11-02	306		12-06	340	21	1-08	8	54
9-30	273		11-03	307		12-07	341	22	1-09	9	55
10-01	274		11-04	308		12-08	342	23	1-10	10	56
10-02	275		11-05	309		12-09	343	24	1-11	11	57
10-03	276		11-06	310		12-10	344	25	1-12	12	58
10-04	277		11-07	311		12-11	345	26	1-13	13	59
10-05	278		11-08	312		12-12	346	27	1-14	14	60
10-06	279		11-09	313		12-13	347	28	1-15	15	61
10-07	280		11-10	314		12-14	348	29	1-16	16	62
10-08	281		11-11	315		12-15	349	30	1-17	17	63
10-09	282		11-12	316		12-16	350	31	1-18	18	64
10-10	283		11-13	317		12-17	351	32	1-19	19	65
10-11	284		11-14	318		12-18	352	33	1-20	20	66
10-12	285		11-15	319		12-19	353	34	1-21	21	67
10-13	286		11-16	320	1	12-20	354	35	1-22	22	68
10-14	287		11-17	321	2	12-21	355	36	1-23	23	69
10-15	288		11-18	322	3	12-22	356	37	1-24	24	70
10-16	289		11-19	323	4	12-23	357	38	1-25	25	71
10-17	290		11-20	324	5	12-24	358	39	1-26	26	72
10-18	291		11-21	325	6	12-25	359	40	1-27	27	73
10-19	290		11-22	326	7	12-26	360	41	1-28	28	74
10-20	291		11-23	327	8	12-27	361	42	1-29	29	75
10-21	292		11-24	328	9	12-28	362	43	1-30	30	76
10-22	293		11-25	329	10	12-29	363	44	1-31	31	77
10-23	294		11-26	330	11	12-30	364	45	2-01	32	78
10-24	295		11-27	331	12	12-31	365	46	2-02	33	79
10-25	296		11-28	332	13				2-03	34	80
10-26	297		11-29	333	14	1-01	1	47	2-04	35	81
10-27	298		11-30	334	15	1-02	2	48	2-05	36	82
10-28	299		12-01	335	16	1-03	3	49	2-06	37	83
10-29	300		12-02	336	17	1-04	4	50	2-07	38	84
10-30	301		12-03	337	18	1-05	5	51	2-08	39	85

SECTION III. DESCRIPTION AND PERFORMANCE

A. Skylab Program

The Skylab is a cluster of four separately manufactured modules and, when assembled in its flight configuration, is 86 feet long and weighs 170,000 lb. Figure 3-1 identifies the individual modules and shows the flight configuration. Module names are derived from module functions or features: the Instrument Unit shown is a functional part of the launch vehicle and becomes inactive once the Skylab is initially activated. The habitable volume of the Skylab is within the OWS, AM, MDA and CSM.

The Skylab was launched on DOY 134 at 1730 GMT (May 14, 1973) from Launch Complex 39A at Kennedy Space Center, Florida. The launch vehicle consisted of the first two stages of a Saturn V. Telemetry indicated that at approximately 63 sec. into the flight, at about the time sonic speed was reached, the OWS meteoroid shield was lost, which in turn broke the tiedown for the OWS solar array wing 2 fairing. The Skylab separated from the second stage at 591.1 sec. after launch. At 593 sec. into the flight the ignition of the retrorockets on the second stage severed the solar array wing that had been released. At approximately 599 sec. after launch, the Skylab entered a nearly circular orbit 234 n mi above a spherical earth's surface, inclined 50 deg. to the equator with a velocity of 25096 ft/sec. The orbital period was approximately 93 minutes.

The loss of the meteoroid shield and solar array wing 2 was determined from evaluation of the telemetry data. A lightweight shield was designed, fabricated, and carried up by the first crew to provide thermal protection for the workshop. When the crew arrived, they verified that the meteoroid shield and solar wing 2 had been lost and the lightweight thermal shield was installed.

Communication between the Skylab and the ground was established over the RF links and was limited to the time it was within range of 1 of the 12 ground sites around the Earth. Approximately 32 percent of the time was covered. Individual site contacts varied up to as long as 11 minutes. In some cases the sites overlap and in others as much as 1.5 hours may elapse between ground site contacts. The site locations and ground coverage are shown in Section VI. The inclination of 50 deg. from the equator was selected to allow Earth Resources and photographic coverage of as much of the earth's populated surface as possible. The upper limit was constrained by launch vehicle performance and safety considerations. The coverage of 50 deg. included most of the populated and food-producing portions of the earth.

Five major objectives were set for the Skylab program: to determine man's ability to live and work in space for extended periods;

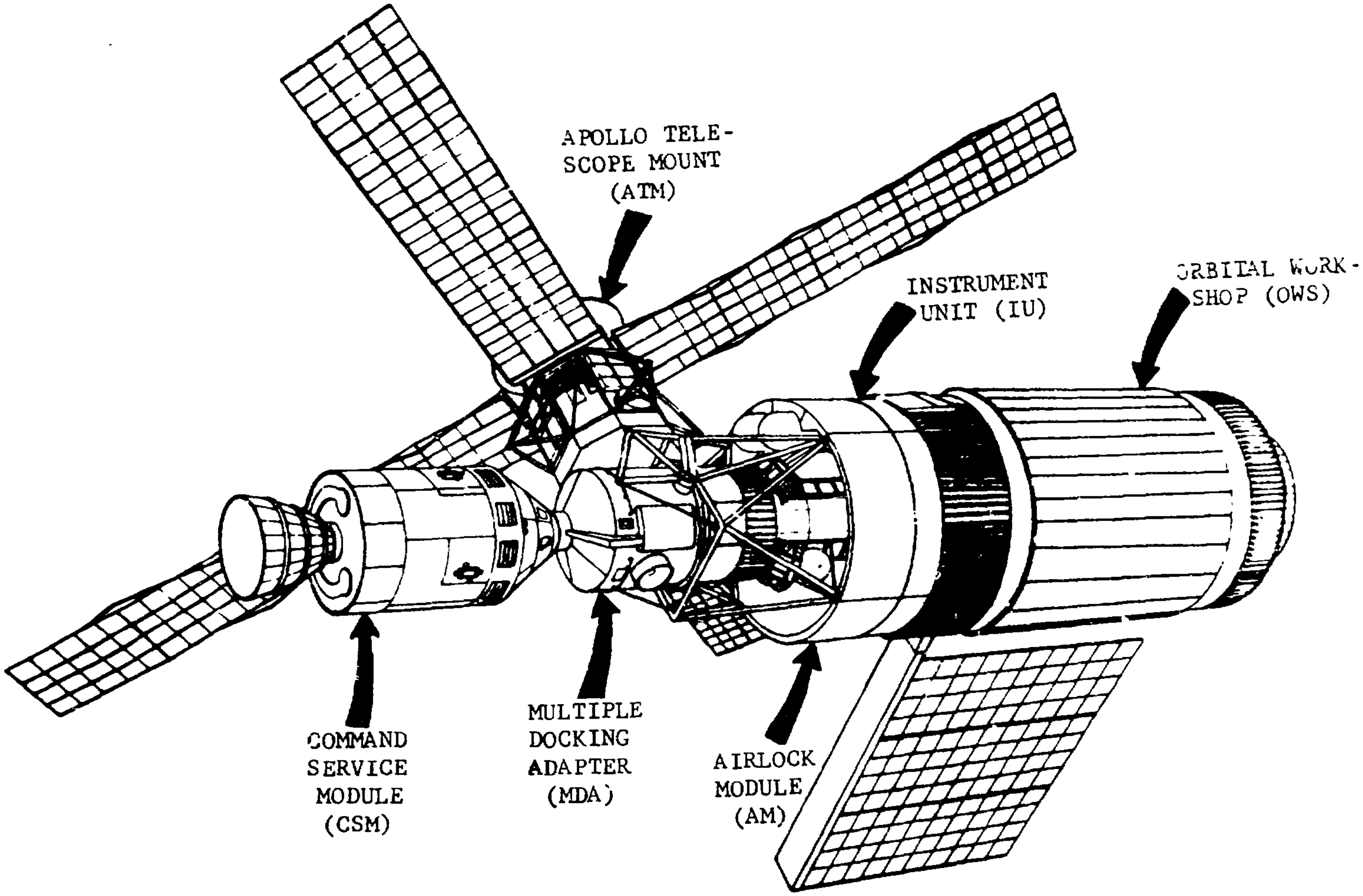


FIGURE 3-1. SKYLAB CONFIGURATION

to determine and evaluate man's aptitudes and physiological responses in the space environment and his post flight adaptation to the terrestrial environment; to extend the science of solar astronomy beyond the limits of Earth-based observations; to develop improved techniques for observing the Earth from space; and to expand knowledge in a variety of other scientific and technological regimes.

The entire mission period was active and consisted essentially of experimentation and station operation. When a crew was on board, the experimentation was greatly increased, and the functions related to habitation were performed, including a degree of crew leisure and recreation. Several activities not originally planned were performed as a result of operational problems. Also the ability to plan and schedule additional experiments, tests, and demonstrations was made possible by crew efficiency.

B. Description of I&C Systems

An overview of the Skylab I&C systems is shown in Figure 3-2. The I&C systems interface with the CSM, the Saturn Instrument Unit, Skylab Experiments, the Spaceflight Tracking and Data Network (STDN), and other Skylab systems. Crewmen voice communication, and engineering and experiment data were essential mission functions and were linked to the ground STDN stations.

Two independent data acquisition and transmitting systems processed the engineering and experiment data for the AM/MDA/OWS and ATM modules. These data from 2060 separate measurements were transmitted in real time when over a STDN ground site. Equipment was provided to record data for playback when contact with a selected STDN station was reestablished.

Two separate Digital Command Systems provided control of AM/MDA/OWS and ATM module functions from the ground. The ground commands controlled many functions, including provisions for hard copy messages to be uplinked to the AM teleprinter and for updates to the ATM digital computer.

The Audio System provided capability for the crewmen to talk with each other from various locations in the Skylab. The intercommunication system was dependent on the audio center in the CSM for normal operation, and interfaced with the CSM S-band and VHF transmitter and receivers to provide voice communication between the crew and mission control. Skylab tape recorders recorded voice during experiment performance or when not in contact with a STDN ground station. The audio system in the Skylab also provided a connection for the astronaut biomedical data.

The Television System, using a portable color TV camera, provided views of the astronauts activities during the performance of experiments, operational and housekeeping activities, and tours outside

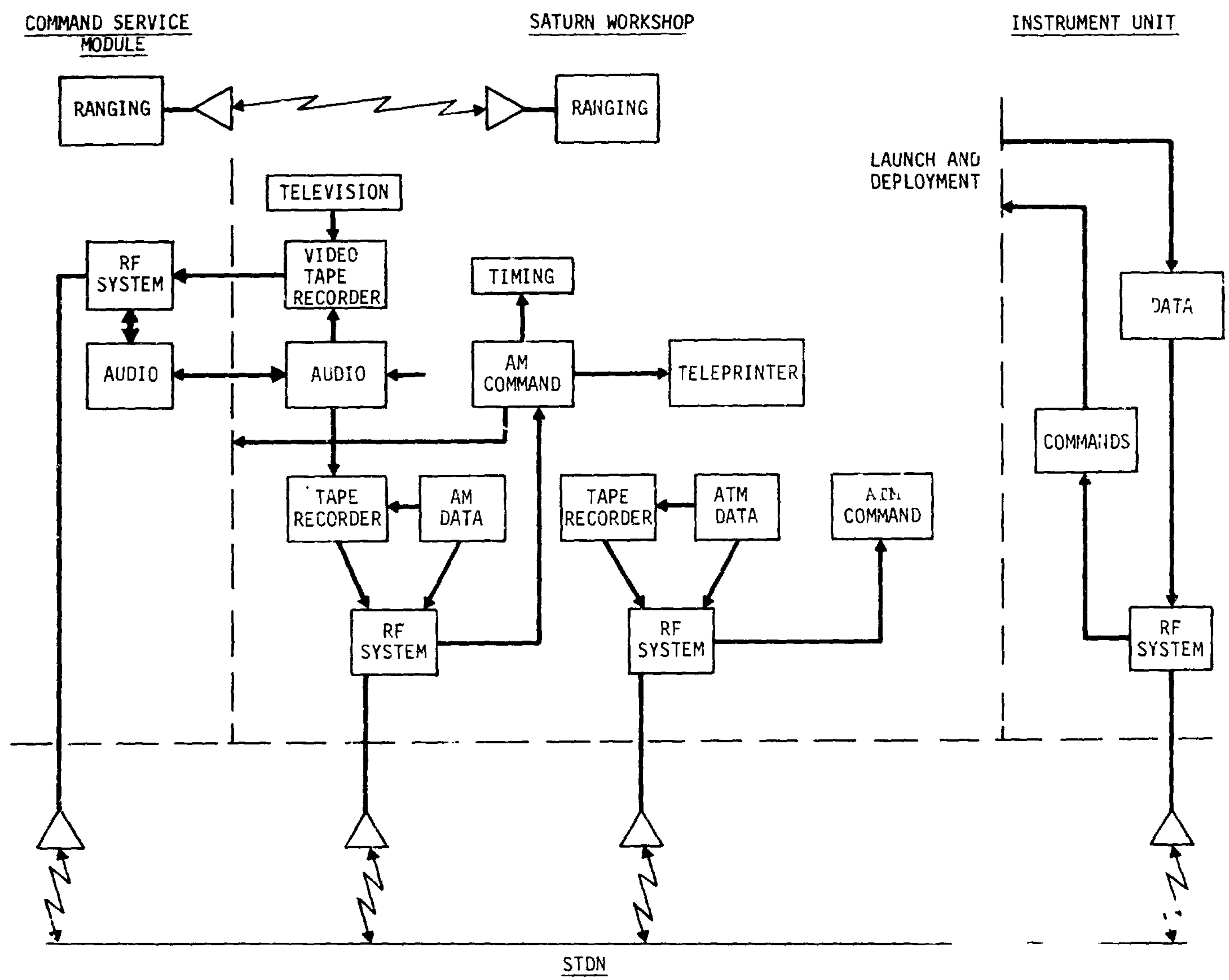


FIGURE 3-2 SKYLAB INSTRUMENTATION AND COMMUNICATION SYSTEM

the spacecraft. The CSM S-band transmitter downlinked video data to the STDN. An onboard Skylab video tape recorder stored video and associated audio for delayed playback. The ATM experiment television cameras interfaced with the Skylab television equipment, and monochrome video from these cameras was downlinked or stored in the same manner as the portable color television camera output. Onboard monitors provided the capability for crewmen to view video data.

A Rendezvous and Ranging System in the AM and CSM aided the CSM in approaching the Skylab.

1. Design Background. Early configurations established a data system for support of the ATM; and a second for AM. These systems were baselined using existing equipment designs. These designs represented equipment from the Saturn program in the case of the ATM and Gemini in the case of the AM. As the program evolved, system configuration changes occurred. These changes in general were directed toward expanding capacity and insuring that the required operating life was achieved.

In the case of the ATM, the addition of remote analog submultiplexers provided additional measurement capacity, and the development of auxiliary storage and playback assembly equipment provided for the storage and recovery of selected data during the periods when RF contact was not available.

The Gemini Data System configuration was modified by adding the interface box. This interface box provided additional channels (obtained by dividing down some high sampling rate channels included in the original format) and made more capacity (subframes) available for recording than the single subframe that was recorded in Gemini. A method of selecting between redundant programmers was incorporated to increase system operating life. As part of the data system, multiple recorders were installed to increase reliability of the recording system and were used when not in ground station contact. Recorder modifications were made to permit recording of digital experiment data on one track and to record voice on the second track.

The Command Systems, like the data systems, used equipment developed for earlier programs; specifically, Saturn IU equipment on the ATM and Gemini on the AM. The systems did incorporate redundancy as is normal for command systems, and the capacity was increased by the addition of the command relay driver units on the AM and switch selectors on the ATM.

The AM Command System had a teleprinter added as an output. This unit operated from a conventional format command signal having a separate system address. This equipment was a unique development for Skylab and was used on a daily basis to provide updated flight plans, menu changes, revised operating procedures, repair instructions and other communications. During development, a major item was the selection of a writing medium that would provide a usable reproduction and also meet the manned vehicle flammability requirements.

The baseline RF systems incorporated redundant transmitters on both the ATM and AM to assure availability of transmitters during the life of the program. The ATM was baselined with 10-watt transmitters while the AM was baselined with the 2-watt Gemini transmitters. Analyses were conducted on the transmitter links and the marginal nature of the AM 2-watt units resulted in a decision to switch to 10-watt transmitters. Another revision in the program resulted in a single 2-watt transmitter being incorporated in the data system, redundant in frequency to one of the 10-watt units, for use during boost and the early flight period. This change was incorporated as a result of analyses that showed the partial pressure from outgassing and evaporative cooling systems in the instrument unit for several hours after launch had the potential of causing corona at the power and potential levels used in the 10-watt units.

The ranging system was incorporated as an aid to the ascending CSM for an efficient rendezvous with the orbiting Skylab. The equipment on Skylab was similar to that carried on the Lunar Module ascent stage in the Apollo program. A high gain directional antenna was designed and installed on Skylab to maximize the distance at which ranging data would be available.

The baseline audio system was an extension of the CSM audio panels to permit headsets to be plugged in throughout the modules of Skylab. Requirements reviews resulted in adding capability for shirtsleeve communication using speakers and microphones. These were contained in Speaker Intercom Assemblies mounted in fixed locations throughout the Skylab.

The Television System was baselined in October 1968. The initial system installed was based on real-time transmission only. Television images to be transmitted included general working scenes throughout Skylab using a modified Apollo color camera and video data from the ATM scientific cameras. An adapter was added to permit the television camera to pick up the image from the viewfinder tracking system optics of the earth resources equipment. System evaluation of possible use of the television brought about the design and development of a remote control lens to be used in conjunction with the scientific airlock and boom system developed for experiment T027. This combination of equipment permitted the extension of a camera outside the Skylab for exterior views. Continued analysis of possible television scenes and available ground contact time resulted in the incorporation of a video recorder in 1971.

C. Performance of Systems

The Instrumentation and Communication Systems performed their roles by providing voice communication during the manned phase and data return during the complete 271 days of the mission. In several cases, spare equipment was installed by the crew, and operational procedures were changed to accommodate maximum communication coverage and data return.

During the launch of Skylab, a portion of the meteoroid shield was lost, which resulted in the loss of one of the solar array wings and damage to the deployment mechanism on the other solar array wing. The telemetry data were used in the evaluation of the sequencing functions, events, and the determination of the associated failure. These problems, coupled with subsequent events, resulted in areas of concern for the I&C system. Available power was reduced due to loss of the solar array wing. The OWS area temperatures also rose above operating limits due to loss of the meteoroid shield, which was also designed to provide thermal protection. This required the vehicle attitudes to be revised to reduce the temperature in the workshop, which in turn lowered the AM Coolant System radiator temperature. I&C mission support, for several days during this period, consisted of providing candidate hardware to power down to conserve energy and providing candidate coldplate-mounted hardware to power up to keep the coolant loops from freezing. This delicate thermal/power balance was maintained for approximately 10 days until the crew arrived and subsequently deployed a parasol from one of the scientific airlocks on DOY 146; and deployed the number 1 solar array wing on DOY 158. During this time some of the I&C equipment operated at off-nominal temperatures. The equipment on the sun side was exposed to high temperatures and the equipment shaded from the sun was exposed to low temperatures. The ATM tape recorders were exposed to high temperatures and reached their upper operating limit. They cooled back to normal operating temperatures when thermal stability was achieved in Skylab with no evidence of deterioration.

The I&C systems performed their required functions during the 271-day mission. The majority of the systems operated continuously for 6506 hours. The anomalies discussed in this report did not basically affect the return of the data. The subject equipment was replaced with onboard spares, redundant equipment was activated, or the problem was transistory and did not affect the mission. The anomalies are discussed in Section VII and the measurements exhibiting some problem during the mission are listed in Appendix A. The remaining 1919 measurements provided data for the full 6506 hours within the normal tolerances.

The ATM Data Acquisition System performed its functions as required. System redundancy was available, if needed, but because of the efficient operation of the primary ATM data acquisition system, the secondary system was not turned on except for end-of-mission testing. A coaxial switch developed a problem on DOY 134, which was manifested by excessively high reflected power compared to the nominal, when transmitter 1 was used with the aft antenna. Normal operation reoccurred, however, when the coaxial switch was commanded to the forward antenna. This anomaly, although restricting the use of transmitter 1 to the forward antenna throughout the remainder of the mission, did not compromise any mission objective nor prevent the ATM data acquisition system from performing its required functions. The original procedure to use a single ATM magnetic tape recorder as a primary unit and a second identical unit as a backup was changed when the thermal problems at time of launch necessitated establishing a use schedule to prevent the tape recorders from exceeding their thermal operating limits. Thus, with the exception of these recorders, the redundant ATM data acquisition system was not activated during the Skylab mission. A 40-hour post Skylab test that energized the redundant system was initiated and satisfactorily completed. This post flight test verified proper operation of both ATM data acquisition systems.

The ATM Command System performed its functions, as required, throughout the entire Skylab mission even though the system was used much more than intended during the first portion of the Skylab mission. No anomalies or discrepancies were attributed to the ATM Command System. Approximately 59,650 commands were executed during the mission.

The AM Data Acquisition System performed its functions as required during the Skylab manned and unmanned missions. Some of the hardware units were operated continuously for the entire mission. However, during the first manned period two AM tape recorders malfunctioned requiring onboard spare unit replacements. The use of the spare recorders at this point in the mission affected the requirement for two spare units to be resupplied on the second manned mission. Also, in this time frame an AM transmitter developed a low signal output and a work-around was initiated that required real-time data transmission normally handled by this unit to be switched to the 2-watt transmitter.

During the second manned mission period the AM Data Acquisition System experienced a third tape recorder malfunction. The crew replaced this unit with an onboard spare. The teleprinter developed a paper feed problem, which caused the crew to subsequently replace the unit with the backup spare unit to regain normal operation. The low-level Multiplexer B output became intermittent. However, alternate and other backup data provided adequate system performance information for the duration of the Skylab mission. Both primary and secondary Time Reference Systems experienced erratic display operation during this time frame. However, by resetting and updating the time reference systems via ground commands, the crew verified proper time displays for both the primary and secondary systems. Normal operation continued throughout the remainder of the mission. The discrepancies and problems encountered by the AM Data Acquisition System during this time period did not compromise mission objectives.

The AM Data Acquisition System continued to perform its required functions during the third and final manned mission. A fourth AM tape recorder exhibited excessive data drop-outs. To restore normal operation the crew replaced it with a spare unit. A noisy second-tier switch in low-level multiplexer P caused eight measurements, common to the switch, to be excessively noisy. Since the tier switch could not be repaired or replaced during flight, the noisy measurements existed throughout the remainder of the mission. The mission objectives were not jeopardized, however, since alternate measurements provided these data. A suspected 3 millivolt signal line short to a 24 volt line in a primary signal conditioner unit caused the AM low-level multiplexers to experience erratic data approximately midway through the mission (DOY 357). The loss of the data from these units was a compromise to the AM Data System but did not impose a restriction on the mission. A quadriplexer corona problem developed on DOY 017 and DOY 020 which caused temporary loss of data from two AM 10-watt transmitters. The 2-watt transmitter provided a good real-time data transmission to the ground. When the corona cleared up the proper transmitter configuration was restored and maintained throughout the rest of the mission. The corona condition was attributed to the venting of an AM cabin relief valve. The above-mentioned problems which developed during the last manned mission of the Skylab program did not negate or compromise the mission objectives.

The AM Command System functioned efficiently throughout the first two manned phases of the Skylab mission. During the third manned mission, a problem developed. A relay in Relay Module No. 3 "hung up" (suspected contamination) in the "set" position, which manifested itself by applying a "fast forward" mode to any recorder selected for experiment data recording. After repeated cycling of commands, the relay was positioned in the "reset" position where satisfactory operation was maintained. The "set" command was subsequently disabled so this problem could not recur. The teleprinter developed an unsatisfactory contrast in printout of messages. This occurred after the crew routinely changed the paper supply. This problem continued until late in the mission when the crew cleaned the teleprinter head.

The VHF ranging system was used during the three rendezvous periods during the Skylab missions for a nominal 4 hours of operation during each period. In addition, the VHF ranging system was operated for approximately 234 hours during the early part of the mission to provide heat into the AM primary coolant loop, to compensate for a primary coolant loop problem. During all three rendezvous maneuvers, docking was accomplished with the Skylab in a solar inertial attitude. This attitude necessitated some off-nominal look angles for the VHF ranging system, and some predicted periods of loss of contact between the CSM and the Skylab. The off-nominal attitude acquisitions did not degrade the crew's capability to acquire and dock onto the Skylab, nor did the off-nominal use of the system degrade its primary function of providing accurate ranging data for the three rendezvous periods.

The audio system performed satisfactorily during the complete mission. Redundant components and work-around procedures were implemented in several cases with no constraints on mission objectives. During the mission, a tape recorder amplifier and an earphone amplifier in Channel B of the audio load compensator malfunctioned. A workaround was initiated using Channel A for the affected Channel B functions. An audio feedback was heard intermittently during communication. With the installation of the antifeedback network, the feedback annoyance was prevented as long as the Speaker Intercom Assembly (SIA) speaker volume controls were kept at a reasonable level. As mentioned at the crew debriefings, direct communication in the 5 psia atmosphere could be maintained for distances between 5 and 8 feet. Beyond that distance the voice level had to be raised or the audio system used. The use of the umbilical/headset was relegated to special situations such as hands-free voice communication in support of experiments or where communication was required and an SIA was not accessible. The crew indicated the SIA's were used approximately 9? percent of the time.

The Television System was used essentially as planned except for imaging outside the spacecraft through the solar airlock. This capability was lost when it became necessary to deploy the thermal shield through one solar airlock and the extension mechanism failed in the other solar airlock during operation of an experiment. The Television System provided video data throughout the mission and the minor equipment problems that occurred were corrected by inflight spare utilization without configuration change. The crew successfully disassembled and removed parts from the failed video tape recorder to bring back to Earth for further analysis. The spare video tape recorder was installed and operated satisfactorily. The video selector switch was also repaired when the control knob loosened from the shaft.

D. End of Mission Status

After the 271 days (6506 hours) of operating time for the Skylab I&C systems, the third crew deactivated and secured the vehicle for indefinite storage. After undocking, certain tests were performed to ascertain the operational status of equipment that either had not been used during the mission or had failed during the mission.

The ATM Data Acquisition and Command systems remained configured essentially as launched until the post mission tests. The backup equipment was energized and operated properly during these checks.

The configuration of the AM Data System at the end of mission was altered by the change-out of tape recorders, the failure of OWS low-level multiplexer B, the failure of the first 8 channels on all AM low-level multiplexers, the failure of an AM 10-watt transmitter and the loss of 141 measurements. The planned consumable replacement items were used as scheduled. The configuration of the Data System at the end of the mission would have adequately supported continued activity.

The AM Command System at the end of the mission was altered only by the replacement of the teleprinter with the onboard spare. The planned consumable replacement items were used as scheduled. The VHF ranging system functioned properly during the rendezvous of the three CSMs, and was powered down for storage.

The Skylab Audio System remained operational with a loss of some redundant equipment. One ALC tape recorder amplifier and one ALC earphone amplifier were inoperative; however, cables were carried aboard to bypass inoperative equipment (if more should fail) and provide the required audio communication. The television system was functioning properly at the end of the mission.

The spares usage and resupply of hardware for the I&C systems are summarized in Tables III-1 and III-2.

Table III-1. I&C System Onboard Spares Usage

ITEM	QUANTITY		
	START MISSION	RESUPPLIED	USED
DIGITAL DISPLAY UNIT	1	0	0
FIRE SENSOR ASSEMBLY	6	0	0
FIRE SENSOR CONTROL PANEL	2	0	1
SPEAKER INTERCOM ASSEMBLY	2	0	2
TAPE RECORDER, AM	4	2	6
VTR ELECTRONICS UNIT	1	0	1
VTR TRANSPORT UNIT	1	0	0
TELEPRINTER	1	0	1
TELEPRINTER PAPER CARTRIDGE	1	0	1
TV INPUT STATION	1	0	1
VIDEO SWITCH	1	0	0
ATM TV MONITOR	0	1	1

Table III-2. Resupply of Hardware

HARDWARE	QUANTITY	USE	REASON FOR RESUPPLY
VIDEO TAPE RECORDER PRINTED CIRCUIT CARD	4	VIDEO TAPE RECORDER COMPONENT	REPAIR DEFECTIVE ELECTRONIC MODULE
TAPE RECORDER REPAIR KIT, AM	1	REPAIR AM RECORDERS	PROVIDE ADDITIONAL ONBOARD CAPABILITY
TV CAMERA POWER CABLE	2	PROVIDE CONNECTION FROM PORTABLE TV CAMERA TO INPUT STATION	REPLACE FAILED POWER CABLE
O-RINGS	4	PARTIAL PRESSURE CO_2 SENSOR	REPLACE O RING SEAL
AUDIO COMMUNICATIONS ANTI-FEEDBACK NETWORK ASSEMBLY	1	ELIMINATE ACOUSTICAL FEEDBACK	PROVIDE ADDITIONAL LOAD ON CSM MICROPHONE INPUT CIRCUIT & ALC INPUT EARPHONE LINE (XMIT MODE) TO REDUCE FEEDBACK.
EMERGENCY TAPE RECORDER VOICE CABLE ASSEMBLY	1	EMERGENCY VOICE DOWNLINK	PROVIDE DIRECT CONNECTION FROM SIA TO AM 10-WATT TRANSMITTER IF CSM FAILURE OCCURRED.
		EMERGENCY VOICE RECORD	PROVIDE DIRECT CONNECTION FROM SIA TO AM RECORDER
LIQUID CRYSTAL THERMOMETER	9	MEASURE TEMP OF RATE GYRO 6-PAK	TO PROVIDE CONTINUOUS VISUAL MEASUREMENTS
ATM TV BUS CONNECTOR MODULE	1	ACTIVATE FAILED BUS	+7D26 BUS FAILED DURING SL-3 ACTIVATION
TELEPRINTER REPAIR KIT	1	REPAIR ONBOARD TELEPRINTER	REPLACE PAPER DRIVE ASSEMBLY.
S-BAND ADAPTER CABLE	1	ROUTE AM DATA TO CSM S-BAND TRANSMITTER	PROVIDE AN ALTERNATE DOWNLINK FOR AM DATA IN THE EVENT OF ANOTHER AM TRANSMITTER FAILURE.

SECTION IV. ATM INSTRUMENTATION AND COMMUNICATION SYSTEM

The ATM Instrumentation and Communication Systems consist of the Data Acquisition, Digital Command, and Television Systems. These systems were designed to perform ATM data acquisition processing storage and transmission, provide command control of the ATM systems and experiments, and aid in experiment operation and pointing for solar data acquisition. This section will discuss the Data Acquisition and Digital Command Systems. The Television System is discussed in Section VI.

A. ATM Data Acquisition System

The ATM Data Acquisition System may more properly be identified as the ATM Data Acquisition, Processing, Storage and Transmission system because it performs each of these functions. This section describes the ATM Data Acquisition System in terms of functional requirements, operational description, and historical evolution.

1. System Description

a. Functional Requirements. The following four requirements controlled the functional design of the ATM Data Acquisition System:

(1) Provide real-time and delayed-time telemetry data.

(2) Transmit real-time experiment and housekeeping data to designated ground stations.

(3) Record preselected portions of ATM data on tape recorders.

(4) Use Saturn-type hardware, where possible, in the system design.

b. Operational Description (Figure 4-1). The ATM data acquisition system design provided the capability for accepting analog, digital, and discrete data and processing and transmitting these data in real time, or selectively storing the data for delayed transmission to a ground station. The 896 data measurements (Table IV-1) were transmitted at 72 kbps to the STDN in real time. Selected measurements were converted to a 4 kbps format and recorded on either of two ATM magnetic tape recorders for delayed time transmission, since the Skylab was not continuously in contact with the ground stations.

Table IV-1. ATM Measurement Matrix

TRANSDUCER TYPE	SYSTEM						
	APCS	EPS	EXP	I&C	TCS	MISC	TOTAL
TEMPERATURE	35	34	129	21	68	2	289
PRESSURE			1		14		15
POSITION	8		6				14
EVENT	68	42	74	38	18	19	259
QUANTITY					1		1
VOLTAGE	24	115	97	53		2	291
ANGULAR VELOCITY	23						23
SPEED	4						4
TOTAL	162	191	307	112	101	23	896

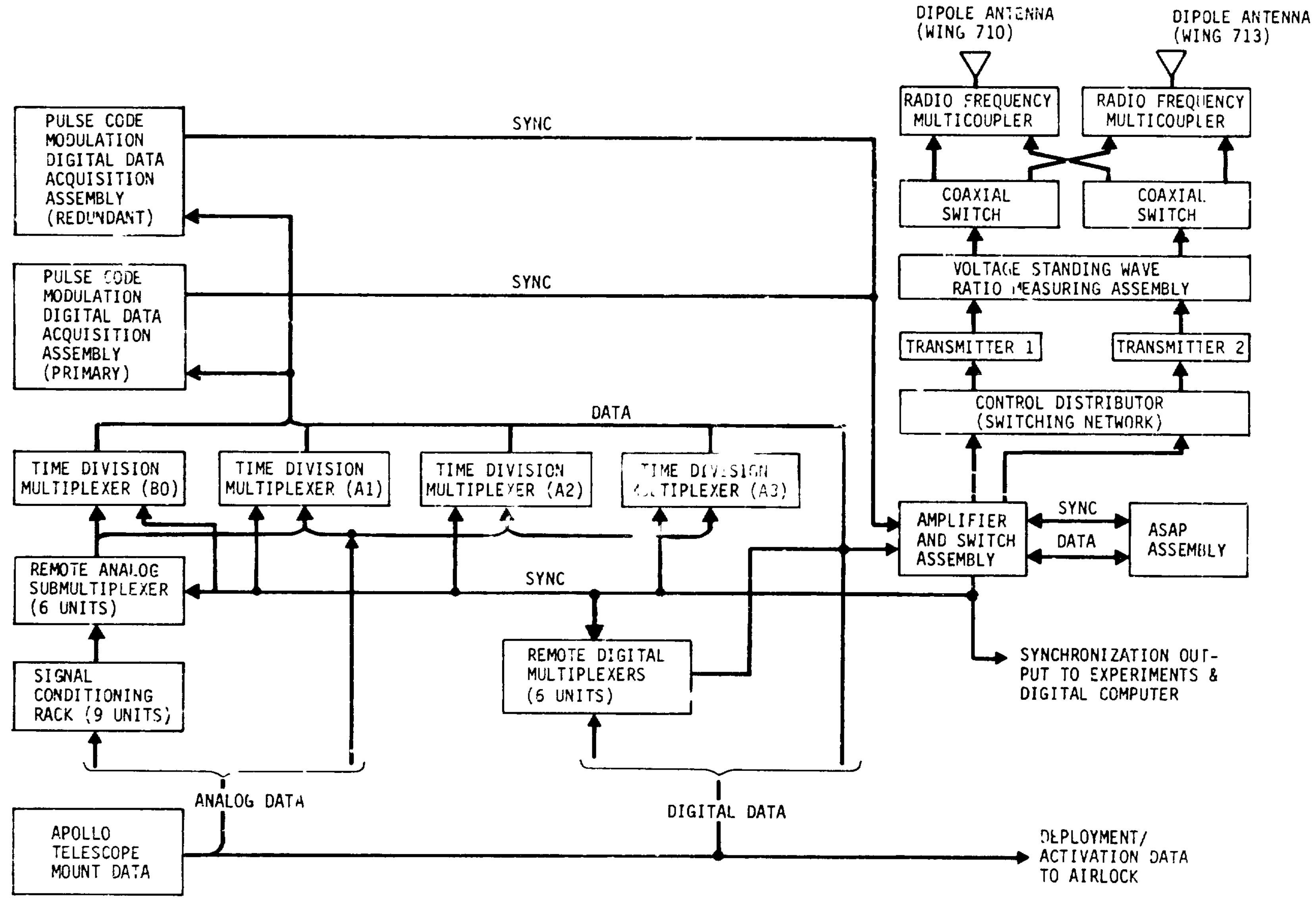


FIGURE 4-1 ATM DATA SYSTEM

The ATM Data Acquisition System processed data from the experiments and systems in the ATM module and consisted of the components described in the following paragraphs.

(1) Signal Conditioner Rack. Each signal conditioner rack conditions up to 40 signals from temperature, pressure, and current transducers and various other voltage sources. The output is 0 to 20 millivolts on all channels. The signal conditioner rack has its own DC-DC converter and is capable of exciting transducers at 6.6 volts at up to 3 milliamps.

There are nine signal conditioner racks in the ATM system. These units were designed for the ATM but were similar to Saturn hardware.

(2) Remote Analog Submultiplexer (RASM). Each RASM samples up to 60 low-level (0 to 20 millivolts) input channels and provides amplified PAM (0 to 5 volts) output to the time division multiplexer. There are six RASMs in the ATM system, similar to the Saturn Model 103.

(3) Time Division Multiplexer. Each multiplexer samples up to 234 high-level (0 to 5 VDC) signals from the RASM, from direct analog data sources and experiment subcommutators, with sampled data being interleaved with amplitude reference data. Resultant PAM output signal is routed to the PCM digital data acquisition assembly. There are four time division multiplexers in the ATM system, similar to the Saturn Model 270.

(4) Remote Digital Multiplexer. Each remote digital multiplexer samples digital data and accepts 100 bits of information, and temporarily stores these data in ten magnetic core registers as ten bit digital words. The words are transferred one at a time to a parallel storage register and held there until the PCM assembly is ready to accept them. There are six Remote Digital Multiplexers in the ATM system, similar to Saturn Model 410.

(5) PCM Digital Data Acquisition System (PCM/DDAS). The DDAS performs analog to digital conversion, sync generation, and formatting. Digital analog signals are generated, encoded into ten-bit digital form, and combined with digital inputs from the remote digital multiplexers and digital data sources. An output format of 30 frames is produced. Each frame contains time slots for 60 ten-bit words, for a total of 1800 words resulting in a master frame of 250 milliseconds duration. The DDAS generates a 144 kHz timing signal from which sync rates of 72kHz, 3.6 kHz, 1/15 pps, 1 pps, 24 pps, and 4 pps are derived. There is a primary and a redundant digital data acquisition assembly in the ATM system, similar to Saturn Model 301

(6) Amplifier Switching Assembly (ASA). The ASA provides switching of data and sync signals between the primary and redundant PCM/DDAS assemblies. It also selects tape recorder outputs from either primary or redundant PCM/DDAS assembly for transmitter modulation. This unit was a new design for the ATM systems.

(7) Auxiliary Storage and Playback Assembly (ASAP). The ASAP accepts parallel ten-bit PCM data and sync signals from the PCM/DDAS assembly by way of the ASA, extracts 400 words/second of preselected PCM data and records it at 4 kbps rate on either of two magnetic tape recorders, each capable of recording 90 minutes. Playback of the recorded data is 18 times the record rate; thus the 90 minutes of 4 kbps recorded data are "dumped" at 72 kbps in 5 minutes. There are redundant (primary and secondary) ASAP units in the ATM Data Acquisition System with a single memory unit used by both ASAP units. These units were designed specifically for the ATM.

(8) Transmitter. The transmitter provides a carrier for the 72 kbps and modulates real-time PCM data and delayed (72 kbps playback) PCM data. The two units are solid state and one transmitter operates at a frequency of 231.9 MHz and the other at a frequency of 237.0 MHz. These units were designed for the ATM.

(9) Voltage Standing Wave Ratio Measuring Assembly. This assembly measures incident and reflected RF power at the transmitter outputs for telemetering to the ground. This unit was designed for the ATM.

(10) Coaxial Switches and RF Multicoupler. These units provide for the transmitter to be connected to either of two antennas or allow both transmitters to be simultaneously connected to either antenna. Two units designed specifically for the ATM were used in the Data Acquisition System.

(11) Antenna. The antennas had the following characteristics: dipole-type with linear polarization; minimum absolute gain of minus 6 dB over 75 percent of radiation sphere; and antenna patterns complementary and nearly omnidirectional. One antenna was located on ATM Solar Wing 710 and the other on ATM Solar Wing 713. These units were designed for the ATM.

(12) Transducers.

(a) Pressure transducers. Two types of pressure transducers were used for ATM housekeeping measurements; differential pressure transducers of the potentiometer type that use 5 volts excitation from the master measuring power supply with ranges of 0 to 30 psig, 0 to 35 psig, 0 to 60 psig, and static error band of 1 percent; and differential pressure transducers with a linear variable differential transformer using 28 VDC excitation with integral power supplies. Ranges are 0 to 8 psid, 0 to 35 psid, 0 to 3 psid and 0 to 0.5 psid with an error band of 0.6 percent.

(b) Temperature sensors. Platinum resistance wire surface and probe-type sensors are used. $R_o \approx 500$, output is 0 to 20 millivolts full scale for each of a variety of measuring ranges. The sensors operate in conjunction with a bridge completion network and excitation source located in the signal conditioner racks.

(13) Other Signal Sources. Events, positions, quantity, angular velocity, and speed signals are fed to the ATM I&C subsystem by the various ATM experiments. These sensors are integral to the subsystems and experiments. Data measurements are sampled at rates of one sample per 15 seconds to 120 sps, depending on specific requirements. There are 896 separate measurements processed by the ATM Data Acquisition System relayed to either of two VHF transmitters that downlink the data in real time whenever contact is established with the STDN. Selected data are recorded by either of two onboard magnetic tape recorders and played back by command.

ATM real or delayed time PCM data are fed to two VHF transmitters where the data frequency (72 kbps) modulates the RF carriers. The two modulated carriers, each with a minimum of 10-watts output power are fed to the ATM antennas through a voltage standing wave ratio measuring network coaxial switch and multicouplers. The network senses and telemeters the incident and reflected power associated with each carrier, and the coaxial switches enable the switching of either or both of the two RF carriers to either of the two available antennas. RF multicouplers directly ahead of each antenna allow the radiation of the two carriers from one antenna.

The ATM antenna system includes two half-wavelength telemetry dipole antennas mounted at the ends of two ATM solar wings. The dipole on wing 710 is mounted in the plane of this wing, while the dipole on wing 713 is deployed perpendicular to the wing's plane with the result that quadrature antenna patterns are generated, which are predominantly linear in polarization and omnidirectional.

c. Historical. The design of the ATM Data Acquisition System was subjected to a series of reviews to define the flight configuration. The ATM Data Acquisition System flight article differed from the original design concept in the following ways.

(1) The antenna coverage was improved by the addition of coaxial switches and RF couplers to the ATM data subsystem. This permitted both transmitters to radiate simultaneously through the antenna that has the best pattern, thereby increasing ground coverage.

(2) The reliability of the ASAP was improved by adding a redundant DC-DC converter, a redundant Data Storage Interface Unit, and reprogrammer for the memory unit.

(3) Redesign of the ASA to provide redundant 1 pps and 1/15 pps sync signal sources was made to provide redundant sync signals to the experiments.

The flight article design was tested and its operation validated prior to installation in the Skylab and again in the normal course of system and vehicle functional and composite checkouts. Simultaneously, failure analysis, diagnostic procedures, and operational procedures were generated and finalized to assure that the ATM Data Acquisition System would satisfactorily perform its role during the Skylab mission.

2. System Performance. The ATM Data Acquisition System was activated 36 minutes after the launch of Skylab on DOY 134 at 1746 GMT and performed satisfactorily throughout the entire Skylab mission. A coaxial switch malfunction restricted the use of Transmitter 1 to the forward antenna; however, no loss of data was attributed to this limitation. It is significant to note that throughout the mission the redundant units of the ATM Data Acquisition System were not needed to support the mission; only the primary units were used. The following paragraphs evaluate ATM Data Acquisition System performance at the component level.

a. Evaluation of Performance.

(1) Data transmission equipment. Transmitters 1 and 2 maintained power output levels of approximately 13.6 watts and 14.4 watts, respectively, throughout the mission with no degradation. Total operating time was 6506 hours for each transmitter up through the termination of the mission.

Coaxial switch operation was investigated in relation to the possibility of causing data dropouts. It was concluded that the coaxial switch operation during a data dump would not cause a data loss; however, the phasing of the antenna may cause a dropout.

(2) Auxiliary Storage and Playback (ASAP). The primary ASAP unit functioned properly for 6506 hours through the entire mission with no malfunction. Therefore, use of the secondary ASAP unit was not required. The two tape recorders were used as described below. The primary Data Storage Interface Unit also operated the entire time. The memory unit functioned properly with no requirement to reprogram the memory by using the internal programmer.

The two recorders on the ATM were coaxial reel, pseudo-loop type machines; each recorded on one track to the end of tape, reversed and recorded in the opposite direction on a second track until reaching the other end of the tape where it again reversed. The total record time capability was 90 minutes per unit and the playback mode required 5 minutes. The recorder operated in a pseudo-loop mode, dumping the oldest recorded data first.

A significant test was performed twice during the Skylab mission to determine the performance quality of the recording system. A comparison was made of data tapes with the real time data as received at the ground site. The bit error rate from this test was 1 in 10^6 or less. This bit error rate for the system was considered excellent since the design requirement for the tape recorder alone was 1 in 10^5.

Following is a tabulation of the tape recorder usage through the end of the mission.

		TEST TIME (HOURS)	MISSION TIME (HOURS)	TOTAL HOURS
Recorder	1	219	3750.5	3969.5
Recorder	2	454	2589.3	3043.3
				7012.8

The loss of the meteoroid shield shortly after launch altered the original plan to run the primary tape recorder continuously during the mission, using the secondary tape recorder as a backup. Thermal stresses on Skylab prompted plotting recorder temperature. It was immediately apparent that continuous operation of a single recorder would cause an over-temperature condition. The management plan was then changed to allow alternate operation of the primary and secondary recorders to maintain recorder operation within the design thermal limits at all times. This plan was in effect throughout the mission. A temperature plot for the typical 24-hour period is shown in Figure 4-2.

The following data management criteria were used during the remainder of the mission

Recording to be continuous, using two recorders as required, to preclude data loss and exceeding recorder thermal limits.

A record cycle of 90 minutes to be used to avoid redundant data.

Dump entire 90 minutes at one site. If not possible, redump entire recording at another site.

Minus 100 dBm to be used, if possible, as threshold for dumps; if below minus 104 dBm, dumps will not be started; and if in progress, will be terminated.

Antenna switching will be minimized during dumps.

Dumps will be planned to avoid using the Vanguard site, when in port, to avoid data dropouts.

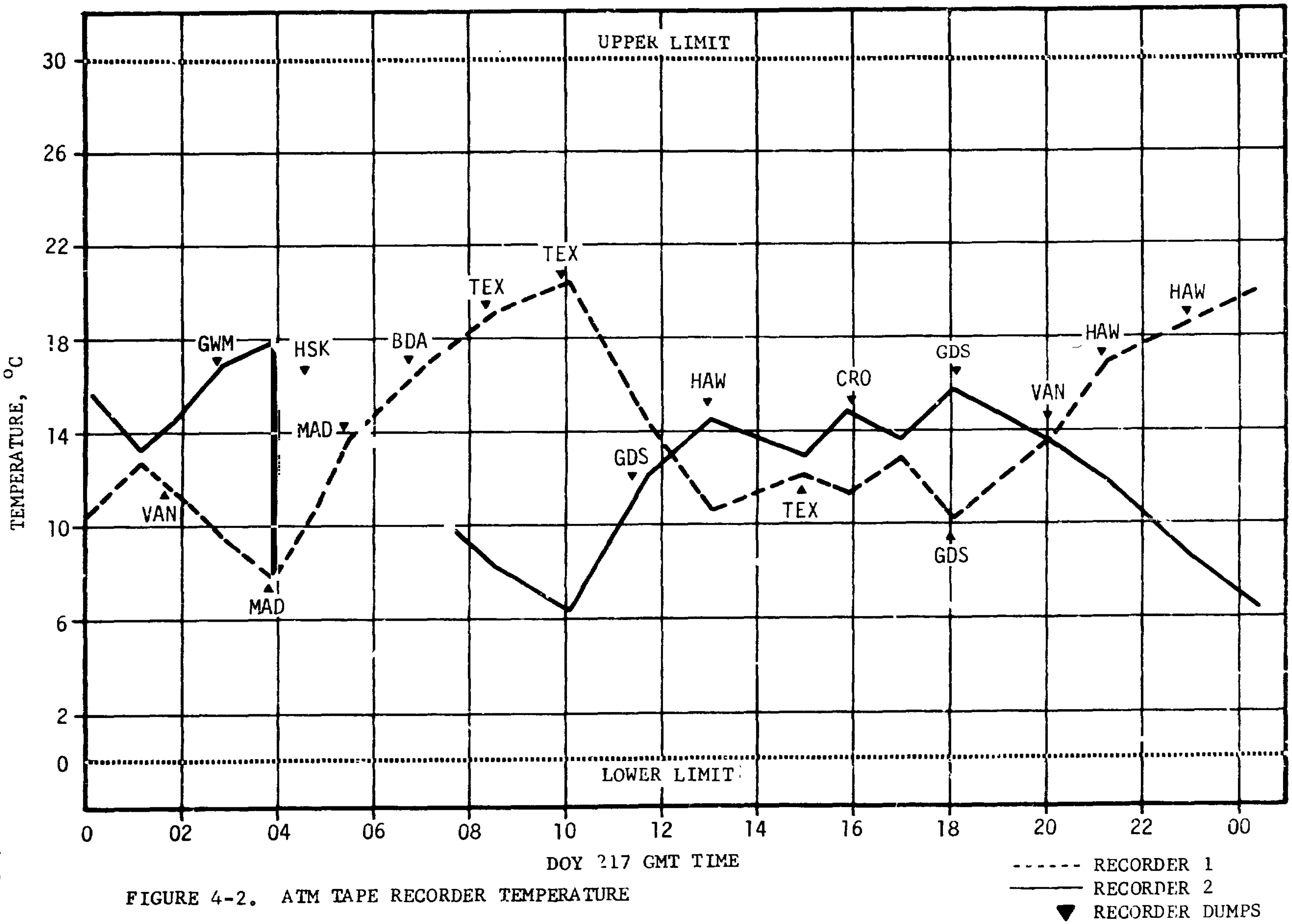


FIGURE 4-2. ATM TAPE RECORDER TEMPERATURE

(g) If possible, dumps will not be started before the site acquisition is 3 degrees or better and will be completed before the vehicle goes below three degrees.

(h) These criteria were optimum and required an occasional violation to retrieve all data.

A test was conducted before Skylab was launched to determine how much data would be lost each time the tape recorder reversed direction and switched heads. This test demonstrated that the data lost was a constant function operating within predictable limits. See Appendix B.

(3) The PCM/DDAS model 301 primary unit operated continuously throughout the entire mission (6506 Hours) with no problem or reason to switch to the secondary system; consequently, the secondary system was not operated. The DDAS processed all PCM data at a rate of 72 kbps, without detectable error. Thus, up through the end of the mission the data system had processed 1.68×10^{12} bits of information with all components functioning normally and well within their design criteria. The DDAS also generated all of the sync signals for the telemetry system, experiments, and the computer. The ASA, which is the distribution system for these sync signals also continued on the primary mode for the full mission with all of the 25 line drivers still in the primary mode.

(4) Multiplexers. All six model 410 remote digital multiplexers that process the 50-bit digital computer word, digital measurements, and experiment data also operated satisfactorily throughout the Skylab mission, providing error-free data.

The four model 270 multiplexers that multiplex the analog data all operated throughout the mission with all channels operating properly. Each 270 multiplexer is capable of time division multiplexing either 27 channels with high sample rates (B_0, 120 sps and A_1, A_2, and A_3 4 sps) or 234 channels at low sample rates (B_0, 12 sps and A_1, A_2, and A_3 40 sps). There may be a combination of high and low sample rates depending upon the internal programming; however, the units are configured for a total of 479 analog channels which includes six model 103 RASMs and 11 experiment submultiplexers. Each of the RASMs will accept 60 channels of low-level data with a 0 to 20 MVDC level into differential amplifiers that have a gain of 250. The 0 to 5 VDC signal is sampled by a 270 multiplexer at 4 sps. All of the 281 channels of low-level data submultiplexed by the six model 103 RASMs operated with no problem.

Each of the model 270 multiplexers and the model 103 RASMs have calibration voltages that were monitored by telemetry. Data presented for RASM No. 3 is also typical of RASM No. 4 and data presented for RASM No. 6 is most typical of RASMs No. 1, No. 2, and No. 5. The ripple noise from the RASMs and the model 270 multiplexers is well within the specification tolerance of 100 millivolts. The calibration voltages were recorded at KSC prior to launch and were telemetered for constant monitoring. Following are typical data that indicate the calibration and reference voltages for the data system have been quite stable and accurate.

EQUIPMENT	MEASUREMENT	LAUNCH	TELEMETRY DOY 140	TELEMETRY DOY 268	TELEMETRY DOY 040
RASM 3	M206	1.067	1.061	1.052	1.061
RASM 3	M207	3.955	3.959	3.938	3.933
RASM 6	M453	1.055	1.035	1.058	1.046
RASM 6	M454	4.125	4.097	4.106	4.056
MUX A1	M535	0.005	0.000	0.010	0.020
MUX A1	M536	4.975	4.974	4.973	4.984

(5) System Anomaly. The following system anomaly occurred and was investigated. See Anomaly Report No. 134 for a more detailed discussion.

On DOY 134 the ATM transmitter exhibited high reflected power. ATM transmitter 1 experienced excessively high reflected power when transmission was switched via coaxial switch to the aft antenna. As a result of this failure, transmitter 1 was operated through the forward antenna for the duration of the mission and transmitter modulation was selected as required to optimize data retrieval.

(6) System discrepancy. On DOY 199 an intermittent decommutator lock was experienced by some ground stations during ASAP playbacks. Tape recorder playback bit error rate was analyzed. This analysis established that a carrier-to-noise ratio to maintain a bit error rate of 10^{-5} on a worst-case ATM delayed-time downlink is less than the FM threshold of 10 dB that has been used for judging a good station contact. Sufficient contacts occur that meet or exceed this standard to provide enough dump opportunities.

Another discrepancy affecting the operation, but not part of the ATM Data System, was the failure on DOY 216 of TV No. 2 Bus during SL-3 activation. A short circuit apparently caused the circuit to burn open. Operation continued on TV Bus No. 1 for the duration of the mission. An investigation of the performance of the ATM system showed that no ATM I&C components were damaged by the short.

b. In-Flight Maintenance and Repair. No in-flight repairs or mantenance were required or accomplished on the ATM Data Acquisition System.

3. End of Mission Configuration

a. The ATM Data Acquisition System remained configured as initially launched on DOY 134. No modifications to any of the system components or spares were required. The ATM Data Acquisition

System operated 271 days (6506 hours). There were no black box failures and no failures in the 308 sensors, 292 channels of signal conditioning, 686 high-level analog channels, 289 low-level analog channels, 228 digital channels, and 391 ASAP channels. There was no degradation of the primary system components at the end of the mission. Appendix A includes a list of measurements that exceeded normal operating limits; the out-of-limits conditions were not attributed to the I&C system. At the end of the mission 889 of the 896 measurements processed by the ATM data system were still providing valid data.

A series of post mission tests were conducted by DOY 040 to evaluate the operation of the redundant equipment that had not been operated during the mission. This equipment included the secondary PCM digital data acquisition assembly, the secondary amplifier and switch assembly, the ASAP memory assembly reprogrammer and the secondary data storage and interface unit. This redundancy verification test was completed successfully as all redundant hardware operated properly.

b. Coaxial Switch No. 1. The switch malfunction placed an operational constraint on the Flight Operations group insofar as determining the antenna-transmitter combination necessary to provide the best data to the STDN. The coaxial switch was not accessible for onboard repair or replacement.

c. Liquid Crystal Thermometer. A requirement developed for a temperature sensing method for use on the six-pack rate gyros in lieu of the onboard portable digital thermometers. A liquid crystal thermometer was recommended and developed. The nine units were prepared and flown up on SL-4. These units had a range of plus 80°F to 120°F. The accuracy was plus or minus 1 percent. These sensors were mounted by the crew on the end of the rate gyro six-pack. The crew verified operation with an onboard digital thermometer.

B. ATM Digital Command System

1. System Description

a. Functional Requirements. The DCS provided the crew with command capability and also provided the STDN with command capability throughout the mission after ATM solar array deployment. The system consists of redundant antennas, antenna couplers, receivers, and command decoders. The antennas receive a frequency modulated VHF carrier from the STDN, and the receivers recover the composite modulation signal. The decoder detects the command word and checks for valid vehicle address. The decoder issues command data signals to address onboard systems directly or through switch selector units. The DCS nominally operates on a carrier frequency of 450 MHz with a deviation of plus or minus 50 kHz and a bandwidth of 340 plus or minus 30 Khz. The DCS has the capability to command up to seven decoder addresses comprising switch selectors and onboard computers.

b. Operational Description (see Figure 4-3). The Digital Command System provides the capability for commanding the ATM systems and experiments during both manned and unmanned periods of the mission. The command code summary is shown in Table IV-2. Command data are transmitted by the STDN in the form of a phase-shift-keyed/frequency modulated signal. The command may be either an ATM switch selector command or ATM digital computer command, and is coded so that only a unique function will be performed in the ATM. Command data can be placed in computer storage at any of the STDN stations. When command data are to be transmitted to the ATM, the data are removed from computer storage, encoded, and transmitted by a 450 MHz ultra high frequency link.

The components of the DCS are configured to provide two independent, parallel systems. Only one operational system is required for processing the command data transmitted by the STDN. During normal operation the STDN addresses both systems. With proper code selection the STDN may address either system individually. This provides total redundancy of the DCS.

A Digital Address System and an RF interrupt switch on the control panel provide the crew with the capability to interrupt command transmissions from the ground, and take control of the switch selectors and computer. The command system is automatically returned to normal operation after a fixed time delay following the execute command given from the onboard control panel.

The DCS consists of two antennas, two directional couplers, two receivers, and two decoders.

(1) The two Command Antennas are different and consist of a Model 316 single-element fixed dipole mounted on the deployable antenna panel located on Wing 710, and a Model 355 deployable dipole antenna orthogonally mounted on Wing 712.

(2) Directional Couplers Model 318, initially designed as Saturn hardware, were used in the ATM to couple ground equipment test inputs to the receivers and to isolate the systems from the antennas during prelaunch checkout. During flight the command message is received by the antennas and coupled through the directional couplers to the command receivers.

(3) Command Receivers, Model MCR-503D, are modified Model MCR-503 receivers originally used as Saturn hardware. The command receivers, which are crystal-controlled, transistorized dual conversion superheterodyne units, operate continuously and simultaneously with an RF input signal of 450 MHz. They have a 340 plus or minus 30 kHz intermediate frequency bandwidth, and after demodulating the signal, provide a dual phase-shift-keyed audio output to the command decoders. The receivers also provided an output to the Memory Loading Unit, which enabled ground stations to load the ATM Digital Computer memory modules in flight.

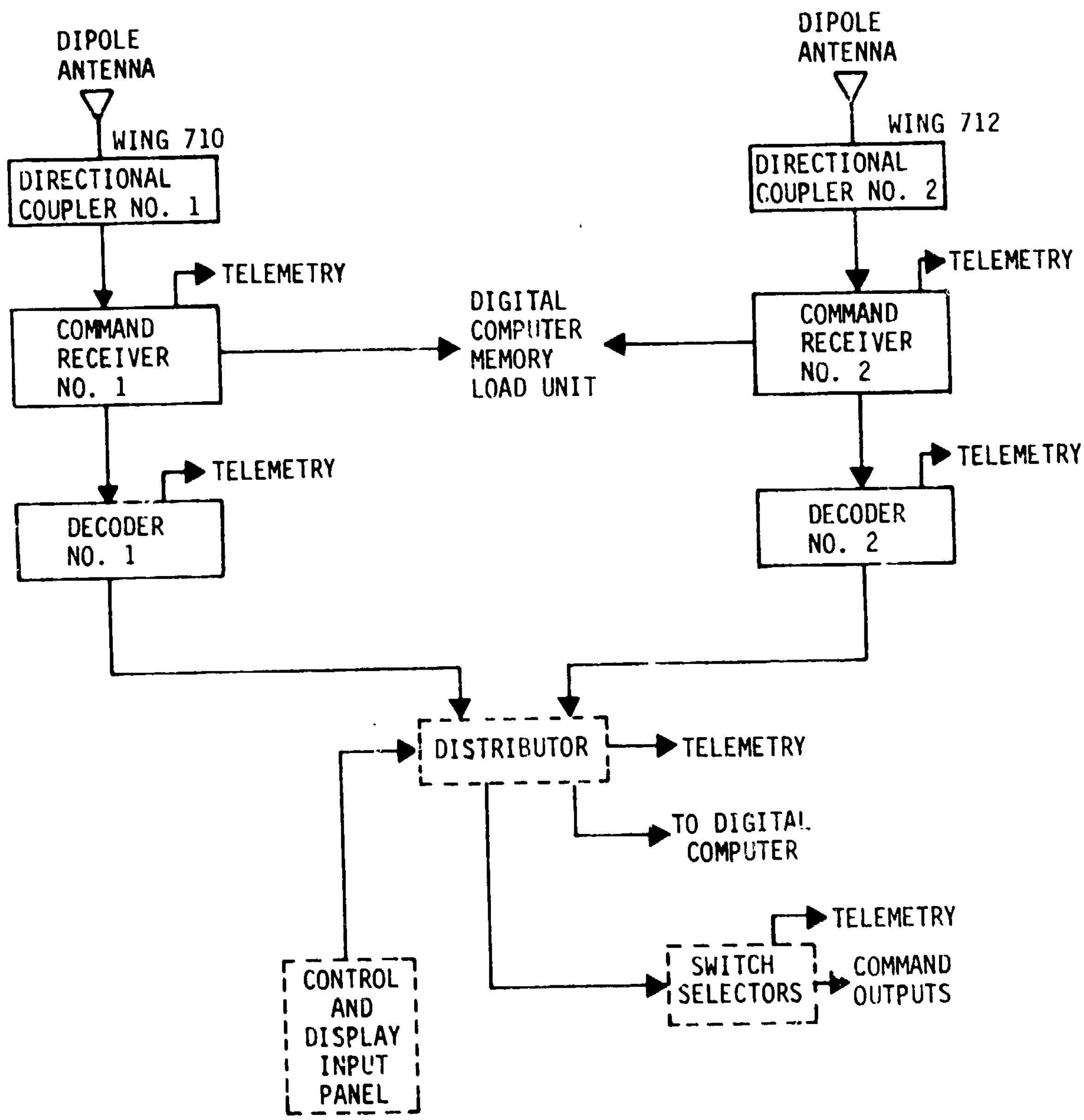


FIGURE 4-3. ATM COMMAND SYSTEM

Table IV-2. ATM Command List Summary

	NO. OF COMMANDS
THERMAL	19
ELECTRICAL POWER	93
ACS	119
TELEMETRY	103
EVA	5
TV	8
S052	17
S054	13
S055A	23
S056	9
S082A	7
S082B	10
H-ALPHA 1	3
H-ALPHA 1 AND 2	2
H-ALPHA 1/S055A	2
H-ALPHA 2/S055A	2
S052/S054	4
S082A AND S082B	4
ACS/THERMAL	4
ZERO TEST	4
REGISTER TEST	4
TOTAL	455
ATMDC MODE COMMANDS	40

NOTE: The ATMDC has a capacity of 16,384 16-bit words in memory. All memory locations are addressable through the command receiver/decoder, as well as through the command receiver/memory load unit.

(4) The Command Decoder received a phase-shift-keyed baseband signal from the receiver, then separated the 1 and 2 kHz signals and compared their phases, resulting in the recovery of the sub-bit data. The decoder also verified the proper vehicle address sub-bit patterns. If the patterns were correct, the data were passed on to the designated subsystems, but if an error was detected the data were rejected and the decoder started the verification cycle over again.

c. Historial. The ATM Digital Command System was subjected to a series of reviews to define the flight configuration. The Command System design was formulated by using previously designed Saturn hardware, with no major changes for this application.

All component and system testing and operation validation was completed before the system was installed in Skylab; after installation the system subsequently experienced and satisfactorily completed vehicle composite testing.

2. ATM Digital Command System Performance

a. Evaluation of Performance. The ATM Digital Command System was activated on DOY 134 and remained in continuous operation for approximately 6506 hours without error or problems during the Skylab mission. On typical manned mission days such as DOYs 225 and 29, approximately 275 commands were processed by the ATM DCS. On unmanned days such as DOY 143 approximately 150 commands were processed. The total of approximately 59 650 commands were executed during the Skylab mission.

Because of the initial failure of the solar array wing and the resulting high temperature problems, the command system was used much more than anticipated during the early days of the mission. In spite of the high use rate, no problems were encountered. All the equipment performed satisfactorily.

b. System Anomalies. There were no anomalies on the ATM Digital Command System.

3. End of Mission Configuration. Both primary and secondary ATM digital command systems were operating normally at the end of the mission. There were no indications of degradation in either system.

No modifcations, constraints, or work-arounds to the system were required during the mission.

SECTION V. AM/MDA/OWS I&C SYSTEM

A. Data System

1. System Description. The initial data system used Gemini program hardware. It was expanded to its present form during the change from the wet to dry workshop concept. This expansion resulted in equipment modifications, additional hardware, relocation of components, and accommodation of MDA, OWS, and selected ATM measurements by this system. Subsequent design changes during the program only added sensors. The final system consisted of sensor/signal conditioners, regulated power converters, PCM multiplexer/reproducers, VHF transmitters, and antennas/coaxial switches.

See Figure 5-1 for a functional block diagram of the Data System.

a. Function. The Data System acquired multiplexed and encoded vehicle systems, and experiment and biomedical data from the ATM, AM, MDA, and OWS, and transmitted these data in both real time and delayed time to the STDN. Some of these data were also made available for display onboard the Skylab for the crewmen. A total of 1164 measurements (548 in the AM, 526 from the OWS, 80 from the MDA, and 10 from the ATM) were telemetered by this system. Some of the basic guidelines followed in developing this system were:

Maximum use of existing flight qualified hardware.

Maximum use of common equipment between vehicles.

Design system for compatibility with the STDN.

Provide ground control over equipment selection and functions with crew control backup.

Provide crew control over experiment and voice recording.

Provide ground control over data downlink.

Provide capability for inflight replacement of selected hardware.

Provide redundancy to meet mission requirements where practical.

b. Operation. The Data System was assembled using existing Gemini program designs where applicable, and/or by modifying these and other designs to accommodate AM/MDA/OWS requirements. New designs were used only where available hardware did not satisfy requirements.

The initial system consisted of 238 channels of PCM telemetry with single tape recorder capability. Program evolution and mission redefinitions resulted in a series of studies to determine the

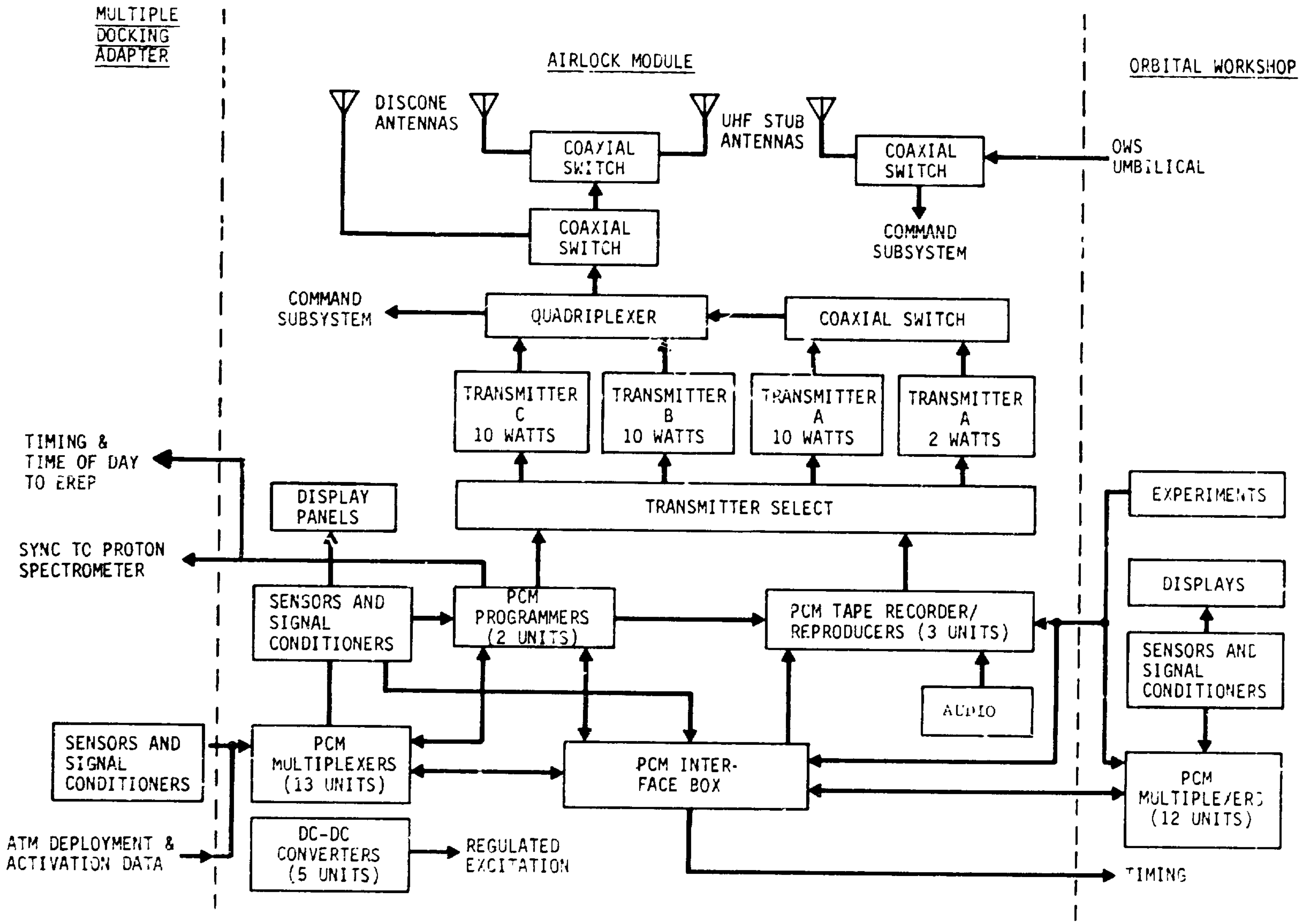


FIGURE 5-1 AM/MDA/OWS DATA SYSTEM

best methods to accommodate the data from other Skylab vehicles; downlink and redundancy alternatives were also considered. It was concluded that an expansion of the PCM multiplexer/encoder equipment in the AM and downlinking data by the VHF transmitters would be the most efficient method to satisfy the new requirements. An interface box was added to the PCM equipment, which allowed use of an increased quantity of low sample rate channels via added multiplexers. A total of 37 multiplexers could be accommodated. The interface box also provided for three additional separate portions of the real time data output to be available for recording; these allowed sufficient housekeeping and experiment data to be available via delayed time. Two additional tape recorder/reproducers and an additional DC-DC converter required for excitation were added. Redundancy for major black boxes was provided. The evolution of the vehicle system design dictated some new sensors, range changes on existing sensors, an increase in the nominal sensor types and additional signal conditioning to satisfy the added functional monitoring requirements. This baseline system provided an increase in telemetry channel capacity to 428 channels with 342 used: multiplexers were located in the AM and OWS.

During the change from a wet to dry workshop concept, the major alteration to this baseline was an increase in the quantity of multiplexers. The system capacity was increased to 629 channels with 535 channels allocated to specific measurements.

Subsequent changes to the Data System included reallocation of multiplexers among the Skylab modules to optimize mission data acquisition and operations. Nominal measurement changes resulting from vehicle and experiment system evolution were also experienced during this period. The final flight system provided 1297 telemetry channels. Remote multiplexers were still located only in the AM and OWS. Data signals from the MDA and selected measurements from the ATM were wired across the appropriate vehicle interface and accommodated by the multiplexing and encoding hardware in the AM.

System control was primarily ground command and crew backup.

c. Sensors and Signal Conditioners. The devices used to monitor life support, physical environment and systems housekeeping data in the Skylab included temperature, pressure, and CO_2 partial pressure sensors, some of which were basic Gemini Program designs, and the gas flowmeter, rapid pressure loss and fire detectors, which were unique to Skylab. The remaining units, acoustic SPL (Instrument unit FM/FM system), dew point temperature, O_2 partial pressure, and quartz crystal microbalance contamination sensors were essentially existing designs modified for AM needs. The signal conditioners fit into all three categories.

d. Regulated Power Subsystem. Five DC-DC converters were provided in the AM and nine in the OWS for the Skylab Data System.

The AM used three for telemetry requirements of Gemini program design, modified for increased power output and two for display functions that were an existing design adapted for Skylab use. These units converted the AM bus voltage of 18 to 32 VDC into regulated voltages of plus or minus 24 VDC and plus 5 VDC. The nine OWS DC-DC converters were a new design and were used for signal conditioners and transducers. These units operated over an input voltage range of plus 24 to plus 32 VDC and provided an output of plus 5 VDC.

e. PCM Multiplexer/Encoder System. The PCM System design was constrained by the requirement to use existing Gemini hardware designs to the greatest extent possible. The programmers and multiplexers were used with only minor modifications; the interface box was a new design using the same construction techniques as the programmer and multiplexers. The environmental design requirements were essentially the same as were required on the Gemini program except for vibration requirements for multiplexers that were to be located in the OWS. A special test was performed that subjected one low-level and one high-level multiplexer to the OWS environment with a random vibration of 25.1 g rms in the most critical axis for 12 minutes.

The SWS PCM System consisted of the following major components: two redundant and switchable programmers, one interface box (redundant electronics), 11 high-level multiplexers, and 14 low-level multiplexers.

The PCM System design allowed interfacing with a maximum of 18 high-level multiplexers and 19 low-level multiplexers.

The Airlock complement, located on coldplates on electronics module number 3, external to the pressurization area of the Airlock, (shown in Figure 5-2), provided an onboard capability for 1297 channels. A summary of system capability is listed in Table V-1

The PCM programmer provided a 51.2 kbps nonreturn-to-zero real-time output for transmission to the STDN, a 51.2 kbps hardline output for use during prelaunch checkout, and a 5.12 kbps return-to-zero output, identified as subframe 1, on the tape recorder system. The interface box provided three additional 5.12 kbps return-to-zero signals to the tape recorder/reproducer subsystem that were identified as subframes 2 through 4.

(1) Programmer. The programmer provided the functions of data multiplexing, analog-to-digital conversion, digital-data multiplexing, and the required timing functions for the interface box. The programmer contained some input gates, but primarily consisted of the circuitry necessary to provide 51.2 kbps nonreturn-to-zero PCM pulse trains to the transmitter and provide 5.12 kbps return-to-zero pulse train signal and clock pulses for subframe 1 to the tape recorder/reproducer subsystem.

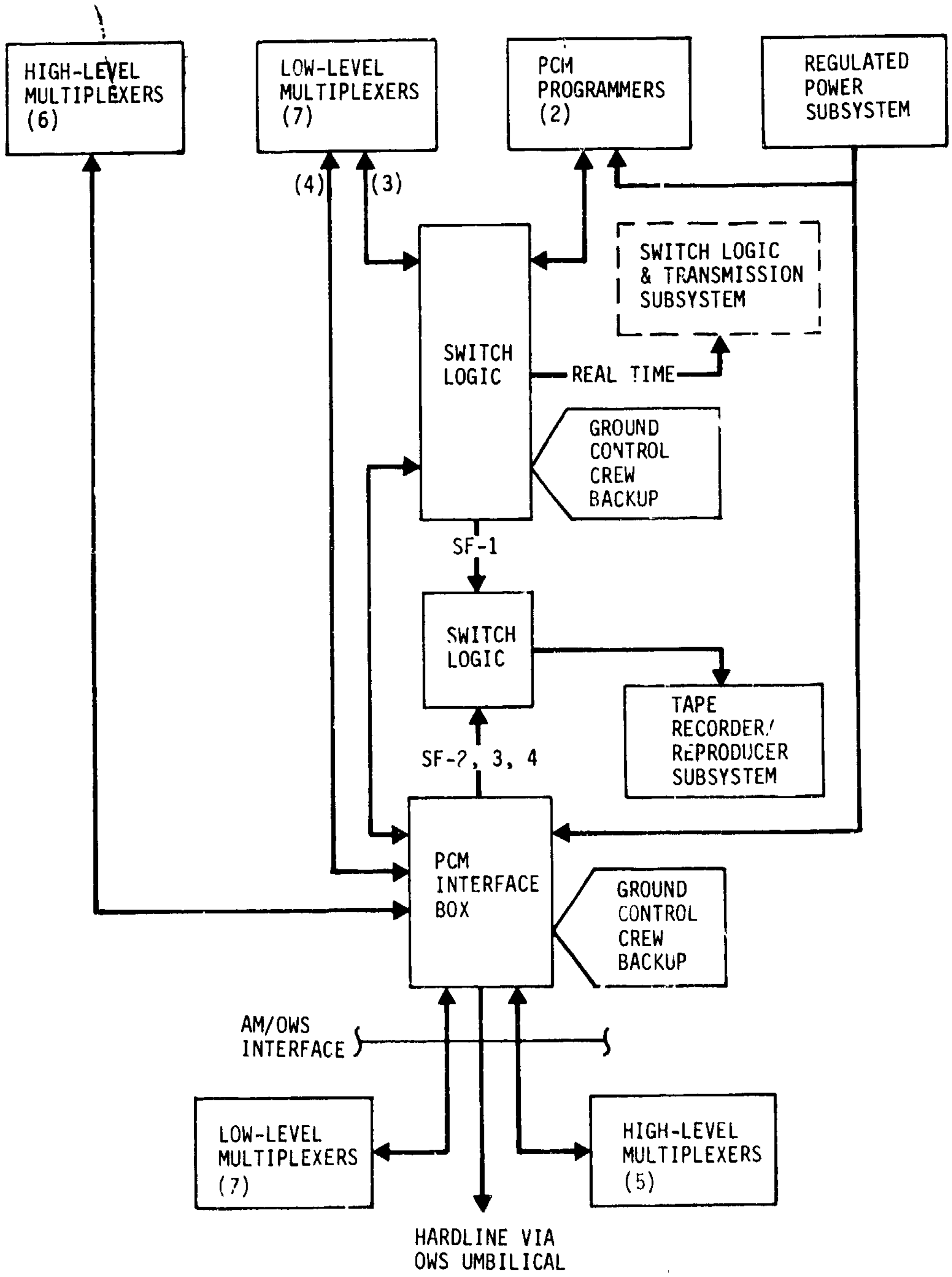


FIGURE 5-2 PCM MULTIPLEXER/ENCODER

Table V-1. PCM Multiplexer/Encoder Channel Capability

SAMPLE RATE (sps)	TYPE SIGNAL	QUAN-TITY	UNIT
320	HL	5	IB
160	LL	6	PROG
80	HL	8	IB
80	LL	9	PROG
40	HL	1	IB
20	HL	5	IB
10	HL	6	PROG
10	HL	18	IB
10	BL	40	PROG
10	BL	192	HL MUX
10	BLP	160	HL MUX
1.25	HL	343	HL MUX
1.25	HL	32	PROG
1.25	LL	112	LL MUX
0.416	LL	336	LL MUX
0.416	SERIAL DIG	24	PROG
	TOTAL	1297	

TOTAL HL ANALOG(0-5 VDC)		418
TOTAL LL ANALOG(0-20 mVDC)		463
TOTAL BILEVEL (ON-OFF)		232
TOTAL BILEVEL PULSE		160
TOTAL SERIAL DIGITAL		24
ONBOARD CAPABILITY	-	1,297

LL MUX	USE	QUANTITY 1.25 sps	QUANTITY .416 sps
B	OWS	8	24
C	AM	8	23
C	MDA	0	1
D	OWS	8	24
E	AM	8	23
E	MDA	0	1
F	AM	8	24
G	AM	8	24
H	OWS	8	24
J	OWS	8	24
L	OWS	8	24
M	OWS	8	24
P	AM	5	15
P	MDA	3	9
Q	OWS	8	24
S	AM	8	22
S	MDA	0	2
T	AM	8	2
T	MDA	0	22
TOTALS		112	336

HL MUX	USE	QUANTITY HL	QUANTITY BL	QUANTITY BLP
B	AM	31	9	16
B	MDA	1	13	0
C	AM	31	0	16
C	MDA	1	0	0
D	OWS	32	0	16
E	OWS	31	0	16
F	AM	31	16	16
F	MDA	1	8	0
J	OWS	32	24	8
K	OWS	24	24	8
R	AM	32	24	8
R	MDA	0	0	8
S	AM	32	24	16
T	OWS	32	24	16
U	AM	30	21	8
U	MDA	0	3	8
U	ATM	2	-	8
TOTALS		343	192	160

(2) Interface Box. The interface box accepted timing signals from the programmer and provided signals to the remotely located multiplexers. It also provided timing signals necessary for the generation and multiplexing of the data in subframes 2, 3, and 4. The programmer provided the 51.2 kbps signal to the interface box where subframes 2, 3, and 4 were separated and prepared for transfer to the tape recorder/reproducer subsystem. Three internal power supplies were located in the interface box. One was used by the internal circuitry in the interface box and the other two provided power to the multiplexers. The interface box was composed of a redundant set of electronics, each capable of full systems operation independent of the other.

(3) High-level Multiplexer. The high-level multiplexer functioned as a high-level analog commutator and an ON-OFF digital data multiplexer. The purpose of this unit was to sample 32 high-level data channels (0 to 5 VDC), 24 bilevel signals (0 or 28 VDC), and 16 bilevel pulse signals (0 or 28 VDC).

All high-level multiplexer analog data outputs were switched through the interface box to the programmer. Each multiplexer was individually wired to the interface box, where third-tier switching was performed before the data were sent to the programmers. Individual third-tier switching was used to prevent a short in one multiplexer line from shorting all other multiplexers and to keep line capacitance at a minimum.

The high-level multiplexer used a slaved timing chain driven by signals from the interface box to support the required sampling functions.

(4) Low-Level Multiplexer. The low-level multiplexer was a differential-input analog commutator that sequentially sampled 32 low-level (0 to 20 VDC) signals. The multiplexer contained a slaved timing chain and digital logic to support the required sampling functions. Operating power and timing slave signals were received from the interface box.

All low-level multiplexers, except E, F, and G were individually switched through third-tier switches located in the interface box. Multiplexers E, F, and G were gated by, and switched through, the selected programmer.

f. Tape Recorder/Reproducer Subsystem. Three tape recorders capable of simultaneous operation provided continuous data coverage during periods when Skylab was out of STDN contact. These recorders were of Gemini program design modified for Skylab. Each recorder received a 5.12 kbps return-to-zero data stream comprising one of the four recordable PCM subframes from the PCM programmer or interface box. These data were recorded on track A, while crew voice was recorded on track B; record speed was 1-7/8 inch per second. Maximum record time was three hours per recorder. In addition to the subframe data, the recorders could also accommodate experiment M509 or T013 data at a bit rate of 5.76 kbps. The recorder played back the PCM data in a nonreturn-to-zero space format into a transmitter; the voice was played back simultaneously into another transmitter. The playback occurred at a speed of 22 times the record speed, and data and voice were played back in an order reverse to what they were recorded. Three hours of data were played back in 8 minutes 24 seconds. Upon removal of the playback command, the recorder switched from the playback mode to the record mode. In the event of faulty data reception, the tape recorders could be rewound at the playback speed for another dump by application of a fast-forward nonrecord command. During this rewind no modulation was present at the transmitter. Figure 5-3 provides a flow diagram of the recording process.

Recorder management was primarily a ground control function. The crew exercised prime control over voice and experiment record functions. Telemetered recorder functions included tape motion and playback mode detection. The crew was supplied with recorder usage lights at all recorder control stations.

Four recorders were launched on Skylab-1 as inflight replacements. These units were installed in the AM lock compartment for launch and were transferred to the OWS for stowage after activation. Two additional recorders were resupplied during the second manned mission.

g. Data Transmitters. The data transmitters required two major changes to arrive at the final flight configuration. These changes were required to comply with program requirements that expanded as the needs of the Skylab vehicle were better identified.

The initial configuration was comprised of two 2-watt Gemini type frequency-modulated telemetry transmitters. One transmitter operated at 230.4 MHz and provided real time PCM transmissions; the second transmitter operated at 246.3 MHz and provided delayed time PCM transmissions. Modulation switching controlled manually or by the DCS would permit either transmitter to be selected for each type of data transmission.

The first major change implemented to the data transmission system added a third telemetry transmitter to enable recorded voice data to be dumped to the STDN simultaneously with the transmission of real time and delayed time PCM. The incorporation of a third telemetry transmitter occurred concurrently with the deletion of the voice subsystem VHF transceivers, therby making available a quadriplexer channel. The initial concept for the third transmitter used a retuned Gemini 2-watt unit; however, tradeoffs between transmitter availability versus ground station signal-to-noise ratio requirements justified incorporation of a 10-watt transmitter.

The second major change to the data transmitter configuration resulted from the data modulation bandwidth requirements being

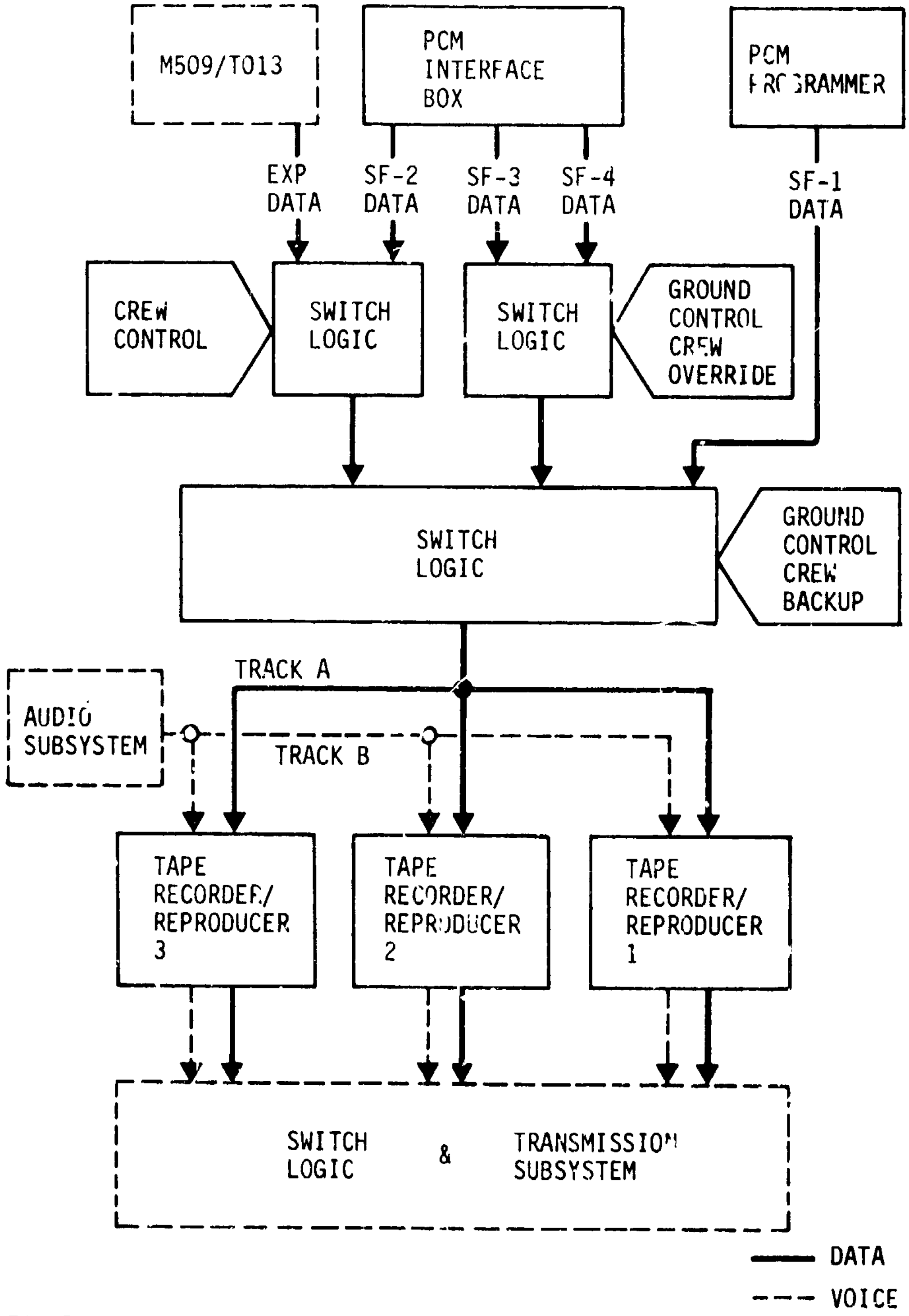


FIGURE 5-3 RECORDED DATA SIGNAL FLOW

expanded to a point where 2-watt transmitters would not produce a satisfactory signal-to-noise ratio at the STDN. A study determined that 10-watt transmitters would provide the needed increase in transmitted power. The final choice of transmitter selection was to utilize existing design and qualified frequency modulated telemetry transmitters previously flown on the Apollo program block 1 boosters. The final flight configuration utilized three 10-watt transmitters and one 2-watt transmitter. The 2-watt transmitter was required to provide real-time telemetry transmissions during the launch phase of the mission because the 10-watt units would cause corona to occur within the antenna subsystem quadriplexer during the period of time the vehicle trajectory passed through the altitude regions most susceptible to corona. After vehicle orbital insertion the launch 2-watt transmitter was to be deactivated and the three 10-watt units activated. Modulation switching, controlled either manually or by ground command, permitted any of the data sources to be transmitted and provided the capability to transmit three data sources simultaneously. The 10-watt transmitters flown were versions of the units that were initially procured, modified to utilize high reliability screened parts and incorporated circuit protection for a shorted output.

h. Antennas/Coaxial Switches. The antennas/coaxial switches required three major changes to comply with program requirements that expanded as the needs of the Skylab vehicle were better identified. The initial antenna configuration was comprised of two Gemini VHF whip antennas, one Gemini UHF stub antenna, one Gemini quadriplexer modified to accommodate a new transmitter frequency, one Gemini diplexer retuned to accommodate a new voice receiver frequency, and one Gemini RF coaxial switch. The antennas provided the capability for reception of 450 MHz command transmissions, reception of 259.7 MHz voice transmissions, and transmission of 296.8 MHz voice, and 230.4 and 246.3 MHz telemetry. The modified Gemini quadriplexer permitted transmission and/or reception of four separate RF signals from either the launch/orbital or orbital antenna. The retuned Gemini diplexer permitted the reception of two separate RF signals from the receive antenna. The coaxial switch provided a means to permit optimum selection between the launch/orbital and orbital antennas.

The first major change implemented to the antenna configuration added two discone antennas mounted on 40-foot extendable booms, a second coaxial switch, and two DCS hybrid rings.

The deletion of the AM voice communication subsystem resulted in removal of voice transmissions at 259.7 and 296.8 MHz, which created the second major antenna system change, deleting the diplexer and the VHF whip antennas. The command/duplex receive antenna, reidentified as the command whip, was retained and used for command receptions only.

The final flight configuration changes required the addition of two coaxial switches and replacement of the UHF whip antennas with modified Gemini UHF stubs. The addition of one of the coaxial switches resulted from a requirement to enable selection between the 2-watt and

10-watt 230.4 MHz transmitters. The other was needed to enable hard-line reception to the DCS receivers during ground checkout. The replacement of the antennas was necessary as the whip antennas could not comply with the redefined structural vibration requirements. The antenna subsystem configuration used during flight is shown in Figure 5-4.

2. System Performance. The Data System was activated during the Skylab-1 launch countdown and continued successful operation during all of the remaining mission phases. The system was operated for a total of 6506 hours without any problems that caused significant impact on the Skylab mission. The AM 2-watt transmitter transmitted real-time telemetry data to the STDN via the launch stub antenna from launch on DOY 134 at 17:30 GMT until 17:52 GMT, when the data system was reconfigured to the AM "A" 10-watt transmitter. The 10-watt transmitter operated into the discone antenna system, which had been deployed at 17:47 GMT. The AM "A" 10-watt telemetry transmitter continued to provide real time transmission of data and transmitters AM "B" and AM "C" were used periodically as planned to provide transmissions of delayed time data, experiment data, and delayed time voice recording. This configuration was maintained until DOY 158 when the AM "A" 10-watt transmitter experienced a reduction of output power. This damage continued to manifest itself until, on DOY 163, the AM "A" 10-watt transmitter was shut down in favor of the AM "A" 2-watt transmitter.

The 1164 measurements monitored by the data system suffered from hardware problems, such as the loss of the meteoroid shield and OWS solar array system wing 2, along with multiplexer problems and individual sensor failures. At the end of the mission, 134 measurements were no longer providing usable information. This represents an 88.5 percent recovery rate for the instrumented parameters. Since these measurements did not fail at the same time but were spread over the entire mission, the actual percentage of recovered data is even greater. See Appendix A for a listing of these measurements. The redundant PCM multiplexer/encoder and DC-DC converter were activated on DOY 357 in an attempt to clear low-level multiplexer noise problems. The equipment operated satisfactorily but the problem remained. The noise problem on the low-level AM multiplexers was evident to the end of the mission (See Anomaly Report No. 357).

The Data System sampled the onboard parameters continuously, 24 hours a day, throughout the 271-day mission. This resulted in 1.28 X 10^{12} data bits output from the encoder. Assuming a 32 percent STDN coverage, over 3.8 X 10^{11} data bits were received by the ground. See Table V-2 for equipment operation time.

a. Sensors and Signal Conditioners. The sensors and signal conditioners performed satisfactorily during the mission with a few isolated problems (See Appendix A).

b. Regulated Power. The regulated power sources performed well within the design requirements for the data system.

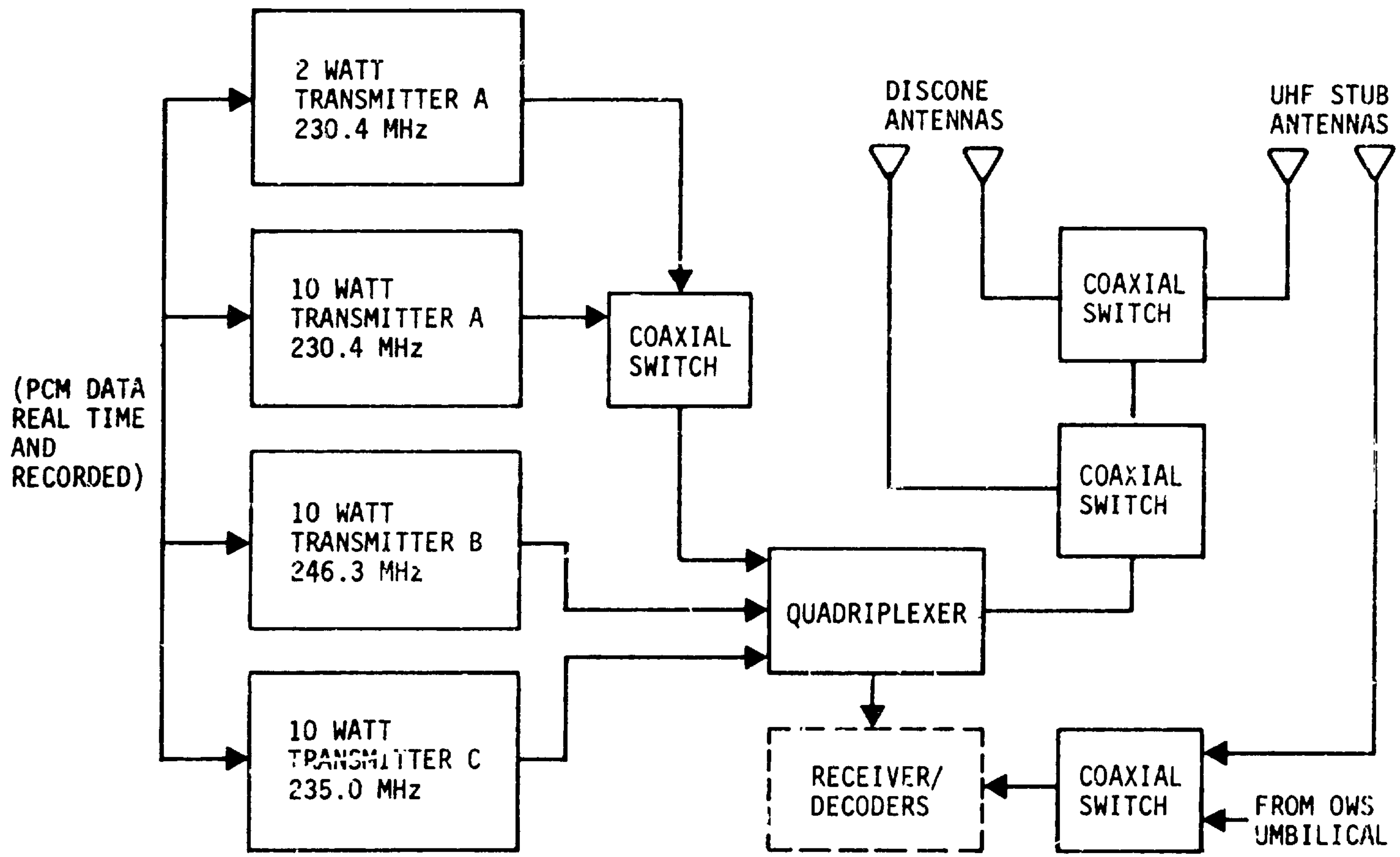


FIGURE 5-4 TRANSMISSION AND ANTENNA SYSTEM

Table V-2. I&C Equipment Operating Hours/Cycle

EQUIPMENT	HOURS	CYCLES
2-WATT TRANSMITTER A	280.0	
10-WATT TRANSMITTER A	710.0	
10-WATT TRANSMITTER B	6330.0	
10-WATT TRANSMITTER C	607.0	
COAXIAL SWITCH (LAUNCH ORBIT TRANSMITTER)		28
COAXIAL SWITCH (STUB/DISCONE 1 ANTENNA)		797
COAXIAL SWITCH (DISCONE ANTENNA)		5479
PRIMARY PCM PROGRAMMER	5344.5	
SECONDARY PCM PROGRAMMER	1182.0	
PRIMARY INTERFACE BOX	5344.5	
SECONDARY INTERFACE BOX	1182.0	
TRANSDUCERS AND SENSORS		
O_2 SENSOR	1969.0	
CO_2 SENSORS	4022.5	
GAS FLOWMETERS	4022.5	
ACOUSTIC MEASURING SYSTEM (IU FM/FM SYSTEM)	4.5	
VIBRATION MEASURING SYSTEM	4.5	
ALL OTHER TELEMETERED SENSORS	6506.5	
SIGNAL CONDITIONING PACKAGES	6506.5	

c. PCM Multiplexer/Encoder. PCM multiplexers, programmers and interface box provided satisfactory data throughout the mission. On DOY 215 the OWS low-level multiplexer "B" became erratic. on DOY 349 the first eight channels of AM low-level multiplexer "P" showed excessive noise, and on DOY 357 the first eight channels of all AM low-level multiplexers plus nine channels of the programmer exhibited excessive noise. These problems are detailed in Anomaly Report Nos. 215 and 349. The total number of data bits encoded and output to the transmitters and tape recorders was increased by 1.9×10^{11} due to the expansion in the mission from 230 to 271 days. This increase in performance was accomplished without any serious degradation to the hardware.

d. Tape Recorder/Reproducers. The tape recorders experienced two separate problems with broken drive belts on DOY 159 and DOY 173, respectively. A third recorder experienced a tape path problem on DOY 256. The fourth and last recorder failure occurred on DOY 019, when the unit began exhibiting excessive dropouts and the problem was not determined. There were two recorders replaced during the mission due to the accumulation of excessive hours. In all cases the recorders were replaced with onboard spares and the system continued to function normally. The tape recorder problems are detailed in the Anomaly Report Nos. 159, 173, 256-1, and 019-1.

The recorders in general performed well. The specified operating time was 750 hours per recorder for seven units, which totaled 5250 hours. Two additional recorders were supplied during the mission increasing this capability to a total of 6750 hours. The actual operating time for the nine recorders used during the mission was 9894 hours, which exceeded the requirements by 3144 hours.

e. Data Transmitters. The data transmitters performed satisfactorily within the constraints of the mission. On DOY 158 the AM "A" 10-watt transmitter experienced a malfunction, which was thought to be the result of corona in the quadriplexer due to venting during the first EVA. The transmitter continued to degrade and by DOY 163 the "A" 10-watt transmitter was putting out less power than the AM "A" 2-watt transmitter (see Anomaly Report No. 163). The mission rules governing transmitter management were revised to prohibit the use of the "A" 10-watt transmitter and replace it with the "A" 2-watt transmitter in combination with the AM "B" and AM "C" 10-watt transmitters for the duration of the mission. On DOY 335 and DOY 353 the AM "C" 10-watt transmitter failed to respond to ON commands over one station but then did respond to the same command over the next station. This problem is speculated as either an intermittent relay contact external to the transmitter or due to malfunctioning output power circuitry internal to the transmitter.

f. Antenna/Coaxial Switches. The antenna/coaxial switches performed satisfactorily throughout the mission. The launch stub antenna provided real telemetry transmissions from launch through orbital insertion. At orbital insertion, DOY 134, 17:46 GMT, the discone antenna booms were successfully deployed. After deployment the discone antennas were used almost exclusively for telemetry transmission. Selections between discone one and discone two were made approximately 5479 times by the command system to optimize antenna coverage.

The quadriplexer performed as expected throughout the mission. On DOY 158 a corona problem was suspected and on DOY 017 and DOY 020 corona due to inadvertent venting for the M509 experiment was confirmed. There was apparently no permanent damage to the quadriplexer and the mission was completed without further incident (see Anomaly Report No. 017).

3. End of Mission Configuration. The configuration of the Data System at the end of mission was altered by the change out of tape recorders, the failure of OWS low-level multiplexer "B", the failure of the first eight channels on all AM low-level multiplexers, the failure

of the AM "A" 10-watt transmitter, and the loss of 134 measurements. The planned consumables replacement items were used as scheduled.

At the end of the mission, constraints were incorporated into the procedures for management of the transmitters and recorders as follows: The AM 2-watt transmitter was being used for AM dump voice. Real-time AM telemetry was on the AM B10 transmitter. AM SF-1 recording was continuous; AM SF-4 was being recorded on a noninterference basis with onboard experiment operation for a maximum of 3 continuous hours each 24 hours. Additional recording was being accomplished as required for system anomalies or experiment operation.

The configuration of the Data System at the end of the mission was satisfactory and would have adequately supported continued activity.

B. Command System

1. System Description. The AM/MDA/OWS Command System consists of the digital command, teleprinter, and time reference subsystems. See Figure 5-5 for a functional block diagram of the Command System.

a. Digital Command Subsystem (DCS)

(1) Function. The functional requirement for the DCS initially was to provide the STDN with a real-time control of the spacecraft switching functions. New requirements were added as the program evolved, which included: redundant receiver/decoders, automatic switchover to redundant DCS, and increase in command capacity.

(2) Operation. The final configuration of the DCS consisted of two receiver/decoder units, four eight-channel relay modules, and a command relay driver unit (CRDU). This resulted in the capability of 540 distinct commands. The original DCS consisted of one Gemini receiver/decoder and two Gemini relay modules providing a capacity of 32 commands (16 set-reset channels). Early in the program two additional relay modules were added, changing the capacity to 64 commands. This system also interfaced with the electronic timer's Tx register. A relay closure from the timer at time Tx provided reset of selected commands.

Reliability considerations resulted in the addition of a second receiver/decoder. A two-vehicle address concept was initiated to maintain individual control over each receiver/decoder; that is, each receiver/decoder was assigned to separate vehicle address. This configuration was chosen to maximize system reliability by providing a fully operational unit, even if a failure should occur in the other.

Switchover between receiver/decoders was automated by the use of the TR capability of the electronic timer. An interface was

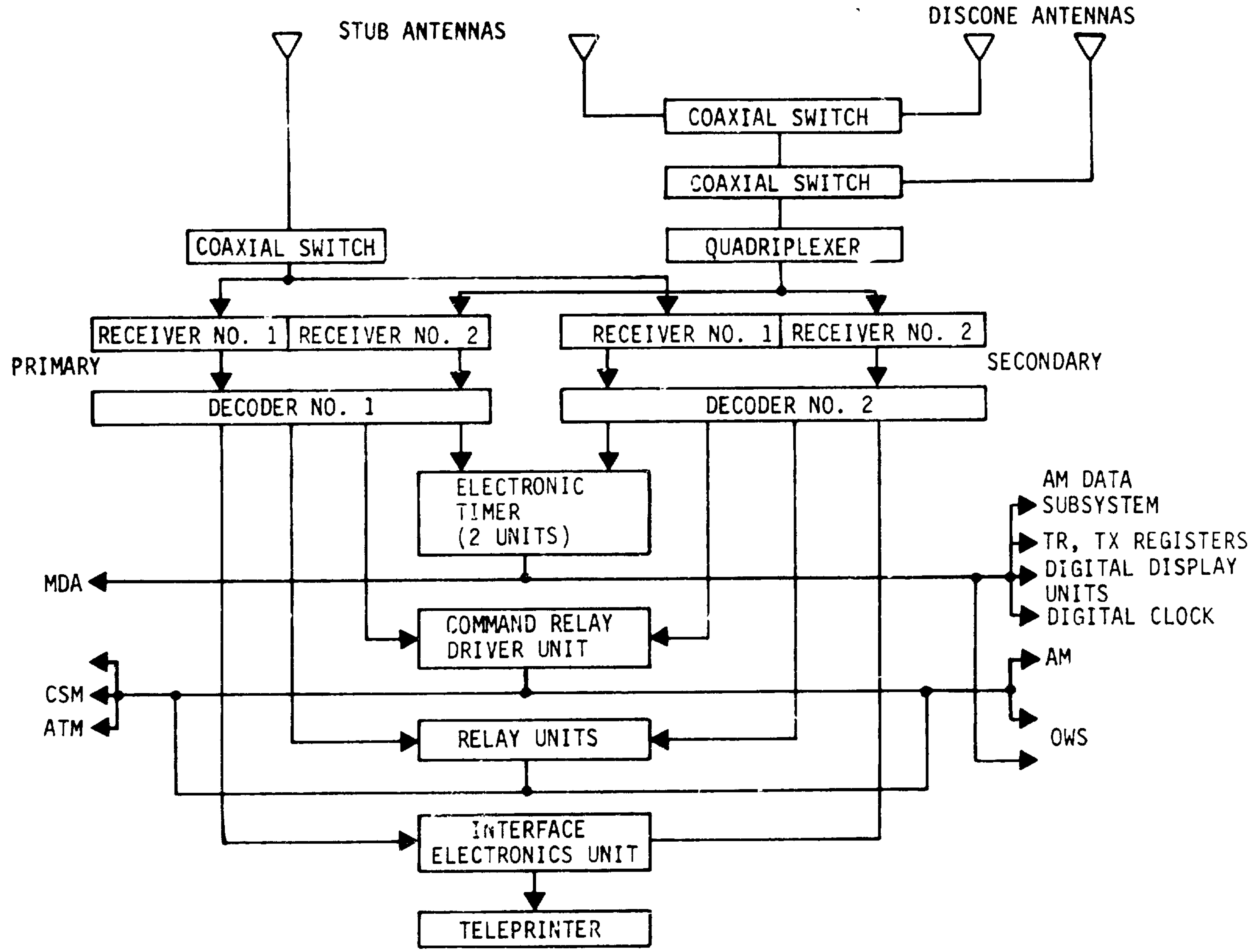


FIGURE 5-5 AM COMMAND SYSTEM

added between the receiver/decoders and the electronic timer to provide an update capability to the TR register. The "TR-30 seconds" relay closure output of the timer was connected to relay circuitry which, if the Tr register was allowed to time out, activated the redundant receiver/decoder. The active receiver/decoder would periodically update the Tr register. Failure to do so, because of DCS failure, would automatically activate the redundant receiver/decoder.

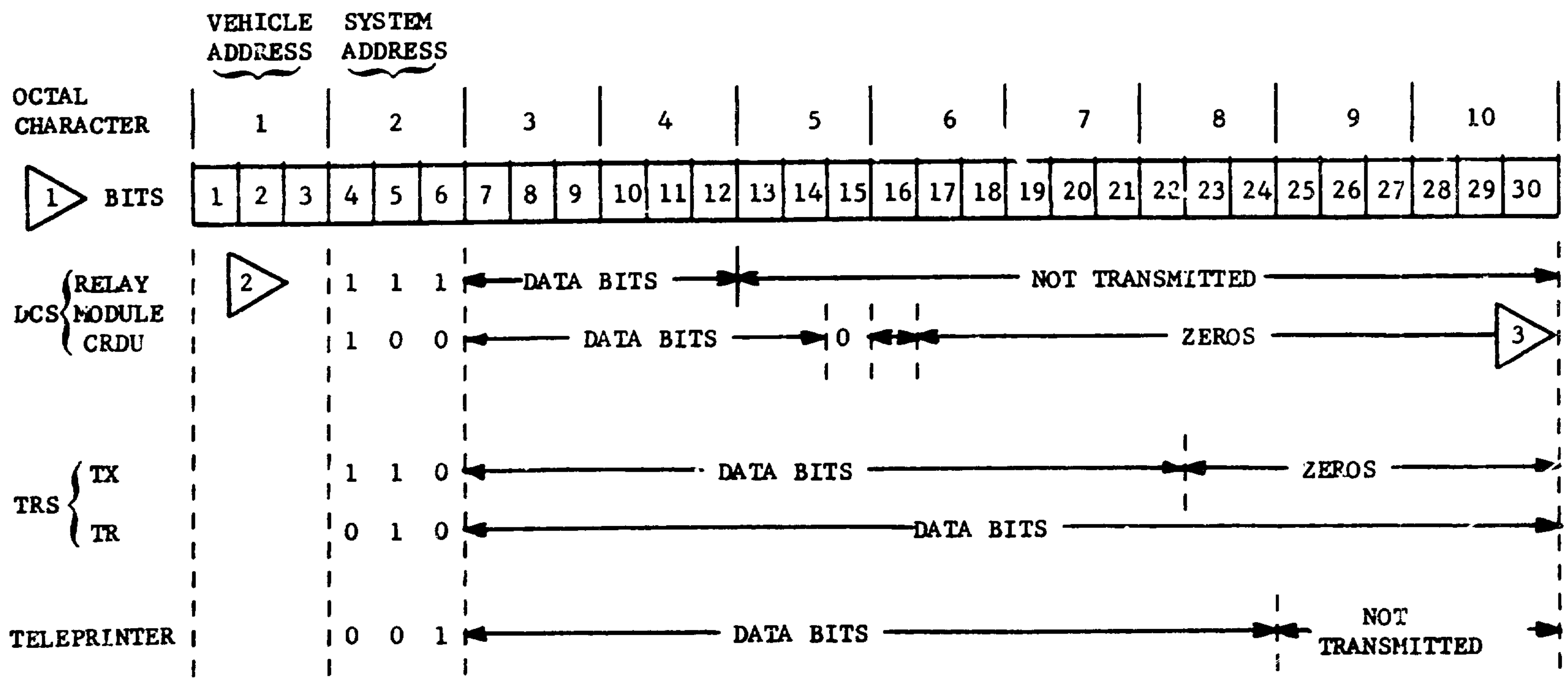
Addition of new command requirements on the DCS required expansion of the capacity of the system. The method for expanding the command capability was through the use of the Gemini receiver/decoder's stored program output that originally provided update capability to the Gemini computer. A new component, the command relay driver unit, was added that used stored program command messages to provide additional pulse command outputs to drive latching relays. The capability to process the stored program commands already existed in the DCS ground station.

The addition of the teleprinter required no modification to the DCS system. An additional system address and output was used to interface with the teleprinter system.

(a) Receiver/Decoder. Each receiver/decoder contained two receivers and a decoder section. Each receiver was connected to a separate antenna and received commands transmitted by the STDN on a phase shift keyed frequency-modulated 450 MHz carrier. Minimum receiver sensitivity was minus 93 dBm. The demodulated signals from both receivers were linearly summed and sent to the decoder. The decoder, after decoding a command, provided either digital data to the electronic timer, CRDU, or the teleprinter subsystem, or a discrete pulse command to a relay in one of the relay modules. Reference Figure 5-6 for command message format.

The Airlock receiver/decoders were of two designs, electrically and mechanically interchangeable. In addition to the original Gemini receiver/decoder a new hybrid unit was supplied that provided interchangeability between units and allowed use of the Gemini DCS ground support equipment without modification.

(b) Relay modules. The Gemini relay modules were used unmodified on the Airlock. Each of the four relay modules contained eight latching relays, each driven by set or reset commands from the receiver/decoders. Thirty real-time command channels were provided, giving a total of 60 set and reset commands. Each relay provided an output to the Airlock telemetry system to indicate its status. The outputs from both the receiver/decoders to the relay modules were in the relay which controlled the receiver/decoders. The command to control the secondary receiver/decoder was available only from the primary receiver/decoder, and vice versa. Thus, a receiver/decoder could not command itself OFF.



1 EACH BIT IS COMPOSED OF 5 SUB-BITS
BIT 1 IS TRANSMITTED FIRST

2 THE VEHICLE ADDRESS IS
PRIMARY RECEIVER/DECODER 010
SECONDARY RECEIVER/DECODER 101

3 BIT 30 IS USED TO MAINTAIN ODD PARITY

FIGURE 5-6. COMMAND CODE FORMAT

(c) Command Relay Driver Unit. The CRDU utilized the Gemini stored program command capability of the receiver/decoders to provide additional real-time commands. It decoded the first 10 data bits of the 24-bit stored real-time command and processed the command into a 200 millisecond, 850 milliampere pulse to actuate a latching relay. The last bit of the command was used to maintain odd parity. The remaining 13 data bits were not used. The CRDU provided digital outputs to the telemetry system to indicate the command message processed.

The original command capacity of the CRDU was 256 commands. Redundant subunits were provided, each interfacing with a receiver/decoder and powered from a separate power supply.

A final design change to the CRDU increased the command capability to 480 commands to meet new program requirements. At this time, the reliability of the unit was increased by elimination of single point failures. Each subunit was redesigned to contain its own output drivers and telemetry output circuitry. The output drivers for each command were connected via diode isolation to a common output pin. The telemetry outputs were tied to common pins via resistive isolation. The current capability of each of the drivers was changed to 850 milliamperes.

b. Tel rinter Subsystem

(1) Function. The teleprinter subsystem was used to provide hard copy data from the ground to the crew. The Interface Electronics unit provided the data conversion interface between the DCS and the teleprinter.

(2) Operation. The Skylab teleprinter was the first hard copy system used in a space application. Subsequent to the initial requirement, a survey of available commercial printing techniques limited the system selection to four basic categories. These were: electromechanical, photographic, magnetic, and thermal printers. The thermal printing technique was selected as the optimum system for Skylab. Selection of a suitable paper required numerous test evaluations and long-term endurance testing to assure environmental compatibility, durability, compliance with flammability requirements, and quality of legibility. As a result of engineering studies, standard thermal-coated military printer paper was selected as the optimum medium.

The teleprinter subsystem received coded digital serial data from either the primary or the secondary DCS receiver/decoder, converted the data into dot matrix form, and printed rows of dots on thermally sensitive paper. These dot rows formed 5 X 7 dot matrix characteristics with a maximum of 30 characters per line. The teleprinter subsystem provided Skylab with the capability of receiving printed messages using any combination of 62 alphanumeric characters at a maximum rate of 1855 characters per minute. The teleprinter paper was a minimum of 120 ft long enabling a print capability of approximately

46,000 five-letter words per roll. Skylab-1 was provided with a total of 156 rolls of teleprinter paper, enabling a total message capability of approximately 7 million five-letter words. The teleprinter subsystem provided telemetry signals for complete message, teleprinter input power, and indicated when teleprinter paper was low.

(a) Interface Electronics Unit. The interface electronics unit provided the interface conditioning between the DCS receiver/decoder and the teleprinter. The interface electronics unit accepted digital data in serial form from the DCS, converted it to the dot matrix format required by the teleprinter, and transferred the resultant information to the teleprinter for printing. The form of DCS teleprinter messages is provided in Figure 5-7.

(b) Teleprinter. The teleprinter was a thermal dot printer producing hard copy messages by electrically heating print elements while in contact with thermally sensitive paper. There were 150 elements arranged in groups of 5 across the 3.25-in. wide paper. The printing process consisted of scanning serially from left to right across the 150 print elements (1 dot row). Each dot pulse received by the teleprinter corresponded to a particular heating element. For each "logic one" received, a thermal pulse was generated energizing the print element and subsequently marking the paper with a black dot. For each "logic zero" received, the corresponding area under the respective print element was left blank. When 1 line had been scanned, the paper was advanced and was left blank. When 1 line had been scanned, the paper was advanced and the 150 elements were again sequentially scanned. The process was repeated seven times to produce one line of alphanumeric characters. Reference Figure 5-7 for a representation of the 62 alphanumeric characters available to the teleprinter subsystem. Reference Figure 5-7 for a message printed by a flight teleprinter. After the final print pulse in a dot row, a line feed pulse is used to advance the paper and reset the scale-of-ten counter so the next data group will be printed starting at the left side of the paper. Two extra line feeds are sent between character lines to provide paper spacing.

c. Time Reference System (TRS)

(1) Function. The TRS was initially required to provide an elapsed time output for the Instrumentation System and a variable time delay control function for resetting command relays. A second variable time delay control function was subsequently required to switch redundant DCS receiver/decoders. The addition of the EREP and of crew GMT displays in the AM and OWS required further use of the elapsed time output, resulting in the need for new display and buffer equipment. A resettable timer was also included to assist the crew with timekeeping functions. Reliability considerations of mission requirements dictated the need for redundant TRS equipment.

(2) Operation. The original TRS consisted of one electronic timer that provided time correlation data to the PCM multiplexer/encoder.

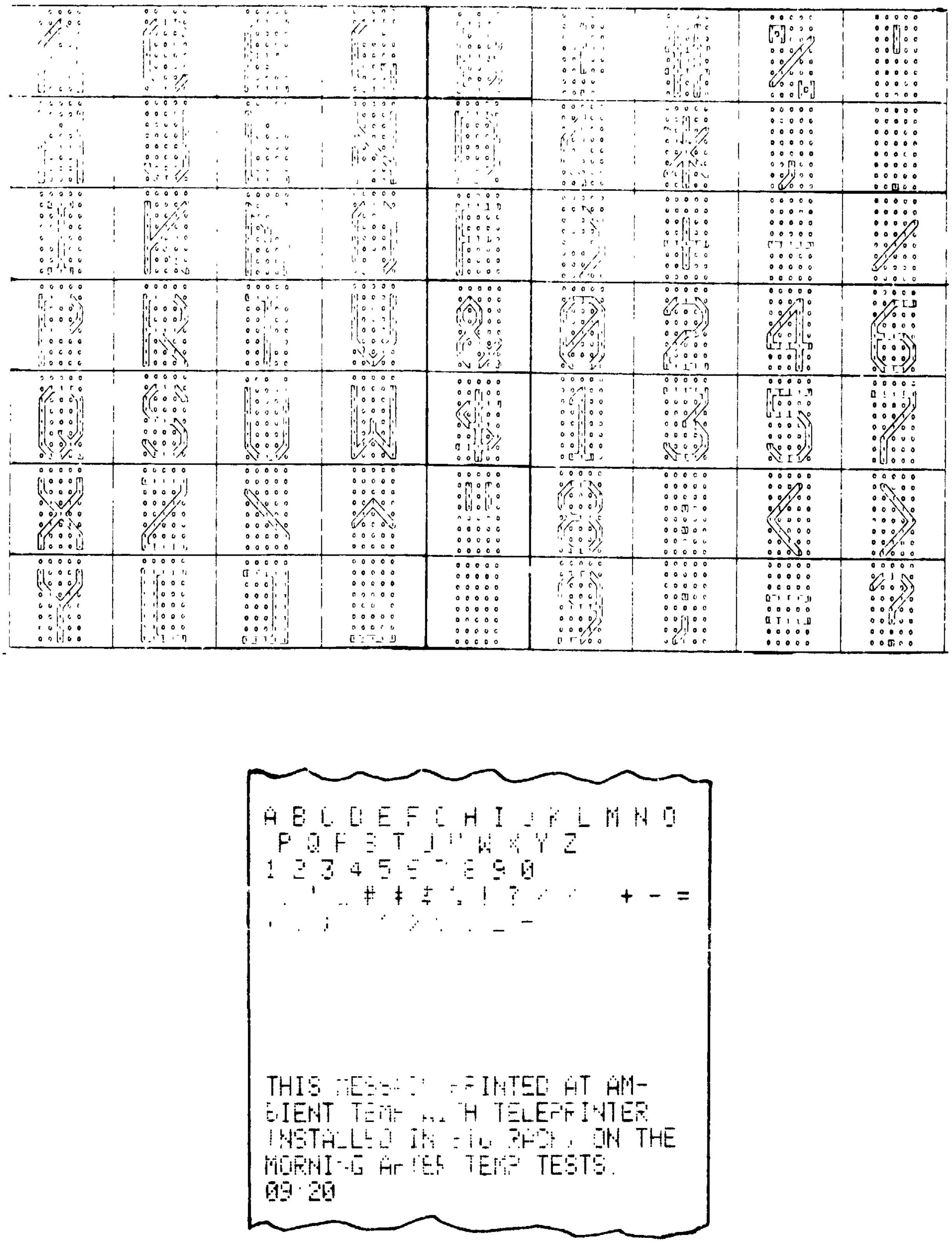


FIGURE 5-7. TELEPRINTER SYSTEM CHARACTERS AND TEST MESSAGE

With the addition of a redundant DCS, the TR-30 sec. output of the electronic timer was used to automatically select the standby DCS. An auxiliary timer was also added to provide automatic DCS switchover after a predetermined time period, in case of electronic timer failure during orbital storage. This method was used in lieu of powering both DCSs continuously, which would have reduced reliability and required more power.

Later, during the design phase, a secondary electronic timer was added to provide redundant time correlation data to the PCM multiplexer/encoder. Selection of electronic timers was controlled by the DCS. The secondary electronic timer TR-30 seconds output was also available to provide the redundant automatic switchover capability to the standby DCS. Therefore, the auxiliary timer was deleted. This design change increased DCS reliability and also reduced power consumption.

The TRS was later expanded to provide time correlation data to EREP and to provide two clock displays of GMT. The clock displays were to be located in the STS C&D Panel and OWS C&D Panel areas. Ground control and inflight control capability for synchronizing TRS elapsed time with GMT were also provided. This addition created the time correlation buffer and the digital display unit. The time correlation buffer converted the electronic timer elapsed time serial binary data into binary coded decimal data for the EREP and digital display units.

The flight-configured TRS shown in Figure 5-5 consisted of two electronic timers/time correlation buffers, one digital clock, and two digital display units. One additional digital display unit was stowed onboard as a flight spare.

(a) Electronic timer. The two electronic timers were powered from separate buses. During the mission, one electronic timer was active while the other was retained in standby. Timer selection was made by the DCS. The electronic timer provided the following outputs: elapsed time data to the PCM multiplexer/encoder and to the time correlation buffer; a countdown of time-to-go-to redundant DCS switchover (Tr) with a relay closure to control the redundant DCS; a countdown of time-to-go-to equipment reset (Tx) with a relay closure to the DCS for resetting relays controlling various equipment; and 8 pps data to the digital clock. The Tx output was also required for synchronization of elapsed time zero with midnight GMT when command enabled. Both elapsed time and Tr were monitored by telemetry.

(b) Time Correlation Buffer. The two time correlation buffers were powered from separate buses. The primary or the secondary time correlation buffer was selected by onboard switching. The time correlation buffer operated in conjunction with the electronic timer to provide time data for the EREP and the digital display units. The time correlation buffer converted the serial 24-bit binary elapsed time word from the electronic timer into two types of binary coded decimal outputs. A serial 36-bit time word was provided to EREP 64 times a second. This time data corresponded to days, hours, minutes, seconds, and fractional seconds through 1/64. The time correlation buffer also supplied a synchronization pulse every 1/32 of a second to EREP for input data synchronization. The time correlation buffer provided a serial 30-bit binary coded decimal data word to the digital display units once every second. The 30-bit data word information consisted of days, hours, minutes, and seconds with a least-significant bit value of 1 sec. Elapsed time data were shifted from the electronic timer eight times a second upon request from the time correlation buffer. There were switches; i.e., 1-day, 10-day and 100-day, provided to manually update the time correlation buffer day register. The time correlation buffer contained a crystal oscillator identical to the electronic timer's and was synchronized with the electronic timer eight times a second. Therefore, accuracy of the data to EREP and digital display units was equal to the electronic timer when compensated for processing delays.

(c) Digital Display Unit. Two digital display units were provided; one was located in the AM STS; the other in the OWS. Their function was to display GMT in days, hours, minutes, and seconds. The two digital display units interfaced with the active time correlation buffer on separate lines and the interface lines were automatically switched to the time correlation buffer selected. Time data were shifted from the time correlation buffer to the digital display unit once per second with a least-significant bit of one second. The digital display unit decoded and converted the binary coded decimal information into drive logic for light-emitting diodes that formed the time decimal display. The power to the digital display unit and brightness of the display were manually controlled by the crew.

(d) Digital Clock. The digital clock in the AM STS received an 8 pps signal from the active electronic timer. The clock was basically an electronic stop watch with a motor-controlled display and was available to the crew for timekeeping functions. The clock was preset by the crew to any desired time between zero and 999 hours, 59 minutes, and 59 seconds. The clock was motor-driven by power pulses that were synchronized to the 8 pps from the electronic timer. Therefore, the accuracy of the digital clock was the same as the electronic timer. The digital clock was manually controlled.

(e) Problems and Solutions. The significant areas of concern resulting from the preflight test phase and their resolution are presented below. A significant discrepancy is one that required component or vehicle modification for resolution.

(1) DCS Receiver/Decoder. During the St. Louis simulated flight test, when both primary and secondary DCS receiver/decoders were powered, a real-time Channel 1 was actuated concurrently with every real-time command sent via the secondary DCS.

Tests showed Channel 32 was similarly affected by the primary DCS. With both units powered, a sneak ground was caused by commonality between the vehicle address recognition logic and the real-time command logic in the decoders. DCS Channels 20 and 21 were reassigned to be used instead of Channels 1 and 32, respectively, by modification of the vehicle wiring.

(2) Command Relay Driver Unit. During the KSC functional tests, command S303 was transmitted; however, the down-link PCM indicated S016 was received. Troubleshooting indicated this condition occurred on the first command transmitted to the AM after command subsystem power-up and was caused by the secondary DCS receiver/decoder or side B of the CRDU. The S/N 104 secondary DCS receiver/decoder was replaced by S/N 106 causing no change in the condition. Further troubleshooting indicated the problem was a flip-flop in the data transfer logic of the CRDU that would occasionally stabilize in a set position when power was applied to the unit. The S/N 101 CRDU was returned to the vendor for incorporation of a diode in the interface and control logic of each CRDU side, which prevented erroneous clock pulses from being generated after power-up. This modification was incorporated in all CRDU flight units. S/N 100 was installed in the AM.

(3) Interface Electronics Unit. In the retest of the DCS timer control relay panel at JSC, the teleprinter began to slew paper. Troubleshooting could not reproduce the problem. Testing at St. Louis indicated the discrepancy was caused by erratic initialization of the print control logic circuitry, which caused continuous line feed pulses to be generated by the interface electronics unit. The interface electronics unit was modified by using an available gate to prevent turn-on transients.

(4) Time Correlation Buffer. During systems level tests, the digital display unit day count of time correlation buffer S/N 102 indicated extraneous day increments during the simulated flight test and random displays were reported during the altitude chamber test. Fault isolation indicated that the minutes and hours of the time correlation buffer were occassionally incorrect, once or twice a day. Random changes to the hour position of the time word caused the day to increment when the day count flip-flop was set. The binary-to-binary coded decimal converter was noise susceptible. For noise reduction, modifications of the time correlation buffer were made by installing a second set of power line EMI filters and by adding capacitors to the internal power supply. Isolation of noise from the signal lines was improved by more shielding, by shorter ground paths, and by twisting and rerouting power lines.

(5) Digital Clock. Digital clock accuracy was out-of-tolerance during the systems validation test at St. Louis. The accuracy of the digital clock was affected by random noise through the clock's power return during the fall time of the 8 pps signal within the digital clock. A 47 K ohm resistor across the data input line improved, but did not eliminate this inaccuracy. The resistor was removed

and the digital clock was modified to eliminate the problem by installing a jumper wire that used an available "one-shot" multivibrator to ground the input inverter during the fall time of the 8 pps signal.

2. System Performance. The AM/MDA/OWS Command System was activated during the launch countdown and continued to operate successfully during all of the remaining mission phases. The system was operated for a total of 6506 hours without any problems that caused significant impact on the Skylab mission. The DCS processed over 100,000 commands with only one failure. On DOY 315, a real-time command reset was sent and the function did not reset as it should have. The teleprinter proved to be a very valuable communication tool and processed uplink messages continuously throughout the manned phases of the mission with only one major anomaly on DOY 219. The crew reported that the messages were compressed and unreadable because the unit had failed to advance paper. The unit was replaced with an onboard spare that was still operating at the end of the mission. The TRS operated within the error band of less than plus or minus 3 seconds per day for 2978 hours before experiencing erratic readouts that required the secondary electronic timer to be commanded ON. The secondary electronic timer became erratic after approximately 583.6 hours of operation, at which time the primary electronic timer was reactivated and normal timing was restored. See Table V-3 for equipment operating time.

Table V-3. I&C Equipment Operating Hours

EQUIPMENT		HOURS
DCS PRIMARY		5319.0
DCS SECONDARY		1292.0
CRDU PRIMARY		5319.0
CRDU SECONDARY		1292.0
TELEPRINTER	S/N 104	137.5
	S/N 100	281.4
INTERFACE ELECTRONICS UNIT		418.9
ELECTRONIC TIMER NO. 1		4673.0
ELECTRONIC TIMER NO. 2		1883.3
DIGITAL CLOCK		4024.5
TIME CORRELATION BUFFER 1		4024.1
TIME CORRELATION BUFFER 2		0.1
DIGITAL DISPLAY UNITS		4024.5

a. DCS. The DCS performed its intended function throughout the manned and unmanned phases of the mission by correctly receiving and processing all function commands, teleprinter messages, and updates to the electronic timer. The primary DCS was used through most of the mission; the secondary system, although not required to meet mission goals, was powered up several times and its command capability was verified at least once during the mission. Both primary and secondary DCS were powered from launch to DOY 137. The secondary DCS was powered down from DOY 137 to DOY 145 to conserve power. On DOY 145 the secondary DCS was activated to serve as backup for the Skylab-2 rendezvous, and then powered down until DOY 273. On DOY 273 the secondary DCS was powered up because the secondary electronic timer was operating and it was desired to maintain the DCS and electronic timer on separate buses to avoid a single point failure. The primary DCS was reactivated on DOY 323 for the remainder of the mission.

On DOY 315 real-time command 19-3 RESET (EXP 2/DATA 2 Recorder FAST FORWARD OFF) was sent and the function did not reset as it should have, as indicated by telemetry parameters K510 (Recorder 3 Motion) and K339 (EXP 2/DATA 2 Recorder Fast Forward). The telemetry indicated that relay K6 in DCS relay module 3, which controls this function, failed to reset when commanded by the receiver/decoder. The relay was successfully reset on DOY 316 and usage of the command was avoided after that. Analyses were conducted using the same type relays of the same vintage. The most probable cause of the problem was contamination between the relay armature and coil that prevented the relay from remaining in its reset state. MSFC conducted an analysis on 10 relays (from relay module S/N 121) and found loose particles of resin flux in each of these relays.

As a result of the above malfunction, two tape recorder "Y" cables were modified to delete the fast forward function. These cables were supplied to KSC for Skylab-4 stowage, but were not flown because the relay had been successfully reset (see Anomaly Report No. 315).

b. Teleprinter. The teleprinter successfully met its objectives for the manned phases of the mission with only one major anomaly, which occurred on DOY 219.

The first series of messages which were transmitted on DOY 145 were reported as faint but legible. The next report from the crew on DOY 148 indicated an improvement in print quality. This light printing was a direct result of the low temperatures in the AM STS at the time of Skylab-2 activation. Testing in the STU/STDN laboratory confirmed that low temperature caused light printing. When the AM temperatures stabilized in the normal vehicle range, the teleprinter message contrast returned to normal.

On Doy 219 the crew reported a teleprinter failure. The messages were compressed and unreadable because of the failure to advance paper. The crew examined the teleprinter and found the paper drive roller was loose and unbonded from the drive bushing, thereby slipping and preventing transfer of motion to the paper. The crew replaced the failed teleprinter (S/N 104) with the onboard spare (S/N 100), which performed normally, completing the Skylab-3 mission. The teleprinter drive roller failure was duplicated in the STU/STDN laboratory. Repair procedures and techniques were developed, using onboard materials in case of failure of the replacement teleprinter. The STU/STDN laboratory was also used to produce video tapes to provide crew training information on the repair procedures. A teleprinter repair kit was supplied to the Skylab-4 crew to be implemented in the event of a failure of the replacement teleprinter. Analysis of the design and manufacturing methods for the teleprinter drive roller assembly failed to reveal the cause for the drive roller/bushing separation (see Anomaly Report No. 219).

There was a basic problem with the teleprinter that seemed to come and go with the normal replacement of paper cartridges. Sometimes after a replacement the crew would report light printing but normally the print quality was good. The reason for this recurring problem was evidently a function of use and maintenance. On DOY 024 the crew cleaned the teleprinter print head with cotton swabs and alcohol and the problem cleared up.

c. TRS. The elapsed time error for the primary electronic timer averaged approximately 0.25 sec/day (fast) while the secondary timer averaged approximately 0.4 sec/day (slow). The digital clock was powered throughout the manned phases of the mission for use as required.

On DOY 237 the crew reported that the AM and OWS digital display units counted erratically. Timing to other systems was observed to be normal (EREP was not activated). The erratic digital display unit readout occurred following installation of the rate gyro six-pack and was considered to be EMI related. The secondary electronic timer was activated and normal timing was restored (see Anomaly Report No. 236-1).

On DOY 266 the secondary electronic timer elapsed time data became erratic after approximately 583.6 hours of operation. The primary electronic timer was reactivated and normal timing data was restored (see Anomaly Report No. 262).

3. End of Mission Configuration. The configuration of the Command System at the end of the mission was altered only by replacement of the teleprinter with an onboard spare. The planned consumable replacement items were used as scheduled.

C. VHF Ranging System

1. VHF Ranging System Description

a. Functional. During rendezvous the CSM transmits a tone modulated signal to the Skylab. A transponder onboard Skylab receives and retransmits the signal to the CSM. CSM computers measure the phase difference of these signals and display the distance between the CSM and the Skylab. The maximum distance for VHF ranging lockup is nominally 300 n mi. The VHF ranging system on the Skylab (see Figure 5-8) consisted of a VHF transceiver assembly and a ranging tone transfer assembly (RTTA).

b. Operational Description. The VHF ranging system was enabled by a Digital Command System command during the rendezvous sequence. The operational sequence of the ranging system is described in the following paragraphs.

A 3.95 kHz tone, amplitude modulated on a 259.7 MHz carrier, was transmitted from the CSM. When this tone was demodulated by the AM transceiver it was detected by a sensor in the RTTA. The activation of this sensor allowed direct retransmission of the 3.95 kHz tone on the 296.8 MHz transmitter in the AM. As this transponded tone was received by the CSM it allowed midrange tracking, which initiated transmission of a modulo-2 combination of the 3.95 kHz signal and a 247 Hz signal. This combined signal was received by the AM and was again transponded back to the CSM. When this combined transponded signal was received by the CSM, range tracking was possible with the 247 Hz signal, as well as midrange tracking with the 3.95 kHz tone.

Automatic tests were performed by the CSM equipment to ensure proper lockup of the mid and coarse range tracking loops. When proper tracking was confirmed, a 31.6 kHz tone was transmitted from the CSM. A 31.6 kHz tone generated in the RTTA was maintained in synchronization with the 31.6 kHz signal received from the CSM. This corrected or synchronized 31.6 kHz signal was transmitted to the CSM. When it was received, the phase difference between the original CSM-transmitted 31.6 kHz signal and the AM synchronized 31.6 kHz signal, minus the predetermined (by testing) value of fixed delays, provided range determination between the CSM and the Skylab. The maximum range was nominally 300 n mi.

The RTTA required an input power of 4.3 watts of unregulated voltage (24-30 VDC) and was located on Electronics Module 5. The VHF transceiver required an input power of 33.5 watts of unregulated voltage (24-30 VDC) and was located on Electronics Module 5.

The VHF ranging helix antenna was installed on the ATM deployment assembly. The antenna was right-hand circularly polarized and had a 3 dB beam width of approximately 50 deg. and a minimum of 8.0 dB gain at 259.7 MHz and 9 dB gain at 296.8 MHz. The antenna assembly consisted of two major parts; a five-turn helix, and a ground plane. The five-turn helix was approximately 53 in. long and 14 in. in diameter. It was centered on a circular plane of 32 in. in diameter.

c. Historical. The VHF transceiver assembly and ranging tone transfer assembly were previously developed and used on the Apollo program. The changes employed on these units for the Skylab program were the replacement of a connector on the transceiver to preclude the

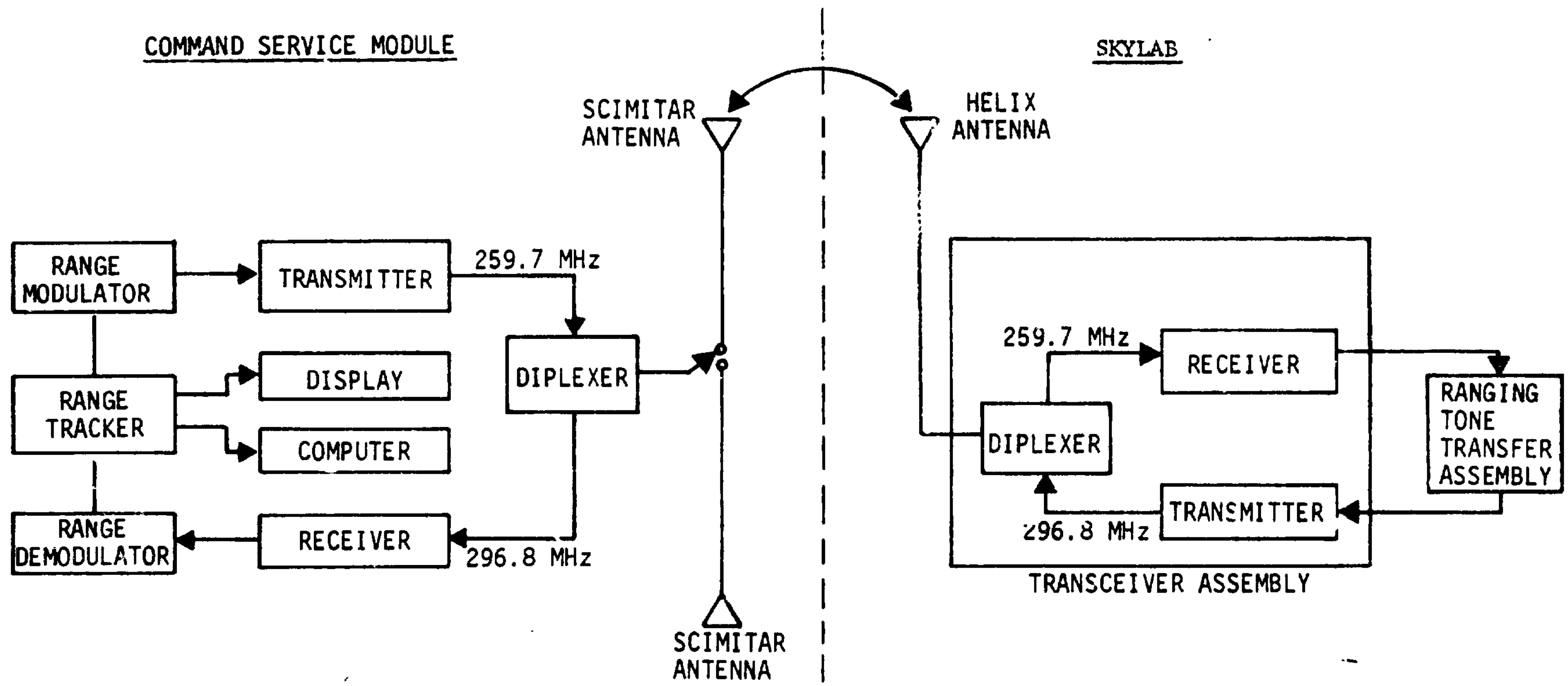


FIGURE 5-8 SKYLAB/CSM RANGING SYSTEM

possibility of improper cabling to the unit, and bypassing the contacts of an unused relay to prevent the possibility of degraded RF output as a result of relay contact contamination. The power supply for the RTTA was redesigned to preclude the possibility of an overcurrent sensor being activated by bus transients and automatically shutting down the RTTA.

2. VHF Ranging System Performance

a. Evaluation of Performance.

(1) Skylab-2 Mission. The VHF ranging system operated during the Skylab-2 rendezvous for 3 hours on DOY 145. During rendezvous, the Skylab was in a 50 deg. pitch-up attitude for thermal control. The 130 n mi acquisition range reported by the crew was considered very satisfactory in view of this off-nominal viewing angle. The VHF ranging system was operated for approximately 234 hours to provide heat into the AM primary coolant loop. This compensated for a primary coolant loop cooling problem that developed prior to Skylab-2 launch as a result of vehicle orientation and lack of sufficient heat load on the cooling system because of vehicle power shortage. This off-nominal usage of the ranging system did not degrade its capability to perform its intended purpose during subsequent missions.

(2) Skylab-3 Mission. The VHF ranging system operated successfully during the Skylab-3 rendezvous on DOY 209 for approximately 4-1/2 hours. The VHF ranging system was activated at 14:22 GMT and initial acquisition occurred at a range of 390 n mi, which is in excess of the 300 n mi specified maximum range. This rendezvous was conducted with the Skylab in a solar inertial attitude because of the reduction of solar power-generating capability as a result of the loss of one OWS solar array system wing. This profile was altered from the premission plan in which the Skylab was in a Z-local vertical attitude during much of the time the rendezvous systems were to be active. The solar inertial attitude caused some off-nominal look angles for the VHF ranging system resulting in some predictable periods of loss of contact between the CSM and the Skylab.

(3) Skylab-4 Mission. The VHF ranging system operated successfully during the Skylab-4 rendezvous on DOY 320 for approximately 4 hours. Ranging acquisition was first attempted successfully at a range of 209 n mi. The rendezvous was conducted with the Skylab in a solar inertial attitude, as in the Skylab-3 rendezvous. Again, some predictable periods of loss of contact were encountered because of the resulting off-nominal look angles. The VHF ranging system had a total operating time of 245.5 hours for the entire Skylab mission with five cycles of operation. The VHF ranging system exhibited no anomalies during the Skylab mission.

b. Inflight Support of Equipment. The VHF ranging system utilized no spares of backup hardware, required no modifications during the mission, and incurred no operating constraints during the Skylab mission.

3. End of Mission Configuration. The VHF ranging system was configured in an off-mode at the conclusion of docking on the Skylab-4 mission. The system met or exceeded all of its design objectives during the mission and was considered to be an operational system at the end of the Skylab-4 mission with no degradation in capability.

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SECTION VI. SKYLAB SYSTEMS

A. Skylab/STDN Interface

1. System Description. Communication requirements between Skylab and the ground network were satisfied by RF links established with the STDN. As many as 12 links were required to satisfy the functions of voice, communication, command uplink, vehicle tracking and ranging, and data recovery. Separate communication capabilities existed on the ATM and AM as well as on the CSM and launch vehicle.

Real-time data, delayed-time data, and voice from Skylab was recovered over VHF downlinks, two from the ATM and three from the AM. Uplink commands were transmitted to Skylab over a single UHF (450 MHz) carrier, and addressed to either the ATM or AM DCS. All real-time voice communications utilized S-band links with the CSM in the primary mode. The CSM FM downlink was also used to transmit television signals from either the portable camera or from the ATM television system. Initial Skylab trajectory following launch and orbit insertion was tracked with a C-band transponder in the Saturn V IU, but only for a short period. During unmanned periods, C-band skin tracking of Skylab was necessary; while active tracking and ranging over S-band links to the CSM performed these functions during manned mission phases. Finally, to assist in rendezvous operations, a VHF ranging link was established between the SWS and CSM until just before docking of the two vehicles.

To support Skylab, a twelve site STDN was used consisting of the following sites shown in Figure 6-1.

Merritt Island, Florida (MIL)

Bermuda (BDA)

Grand Canary Island (CYI)

Ascension Island (ACN)

Carnarvon, Australia (CRO)

Guam (GWM)

Hawaii (HAW)

Corpus Christi, Texas (TEX)

Goldstone, California (GDS)

Madrid, Spain (MAD)

Honeysuckle Creek, Australia (HSK)

USNS Vanguard (VAN)

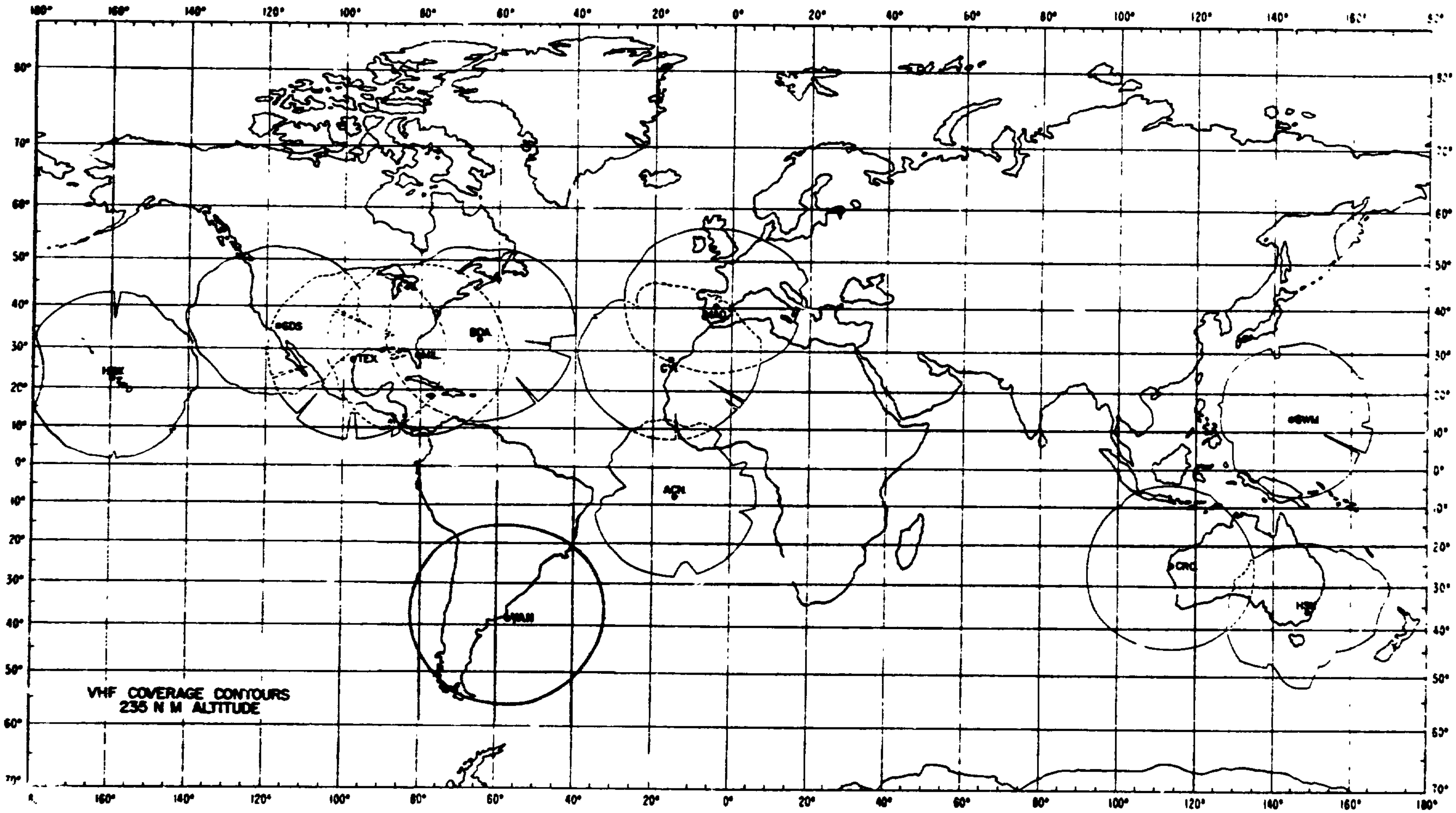


FIGURE 6-1. SKYLAB STDN CONFIGURATION

In addition, limited support capabilities were used at the Newfoundland and Tananarive sites.

Each of the 12 STDN sites was capable of receiving Skylab telemetry, transmitting uplink commands, and two-way voice communications and S-band tracking. Special facilities were available at the GDS, TEX, and MIL sites for the reception and processing of TV data. All data distribution between tracking sites and control centers used the NASA communication network of landlines and microwave links under control of the GSFC.

The VAN location during the entire mission was in the vicinity of Mar Del Plata, Argentina, at approximately 302°40'E longitude and 38°00'S latitude. During SL-1/SL-2, the VAN was positioned in harbor, but it experienced radio frequency interference, and was later positioned about 50 miles offshore.

a. SWS Antenna System. Several independent antenna systems were active in accomplishing the Skylab communications functions. The Skylab illustration presented in Figure 6-2 locates the various antenna elements and briefly describes their characteristics and applications.

The ATM antenna system consists of four separate antennas located on three of the solar panel wings. Two of the four elements are telemetry and two are command. An antenna panel is located at the end of wing 710, and it has two omnidirectional half-wavelength dipoles mounted in the plane of the panel. The telemetry antenna was used to radiate the ATM telemetry carrier frequencies at 231.9 and 237.0 MHz; it is commonly referred to as the forward antenna. The other telemetry antenna, located on wing 713, is referred to as the aft antenna. It also is a one-half wavelength dipole, but is a deployable unit that, when deployed, is perpendicular to the solar wing. The command antenna located on wing 712 deploys similarly, and is a one-half wavelength dipole also. Both command antennas receive data over a 450 MHz carrier.

The ATM telemetry antenna on solar wing 710 produces antenna gains over 84.5 percent of its pattern which result in a positive circuit margin at the STDN receivers when transmitting 10 watts over maximum slant range. The antenna on wing 713 produces such antenna gains over 93 percent of its pattern. ATM command antennas provide gain levels over 99 percent of their individual patterns sufficient to yield positive circuit margins at maximum range.

The AM antenna system consists of two boom mounted and two flush mounted units. The two omnidirectional, discone antennas are located at the end of two booms about 40 feet in length which extend out from the AM in the +Z axis of the SWS. These antennas radiate the three AM telemetry carrier frequencies at 230.4, 235.0, and 246.3 MHz and also receive command data at 450 MHz. In addition, two stub antennas are flush-mounted on the AM-fixed airlock shroud, as indicated in Figure 6-2. The launch stub radiates the three telemetry signals indicated above and receives the 450 MHz command carrier. The command stub receives only command data.

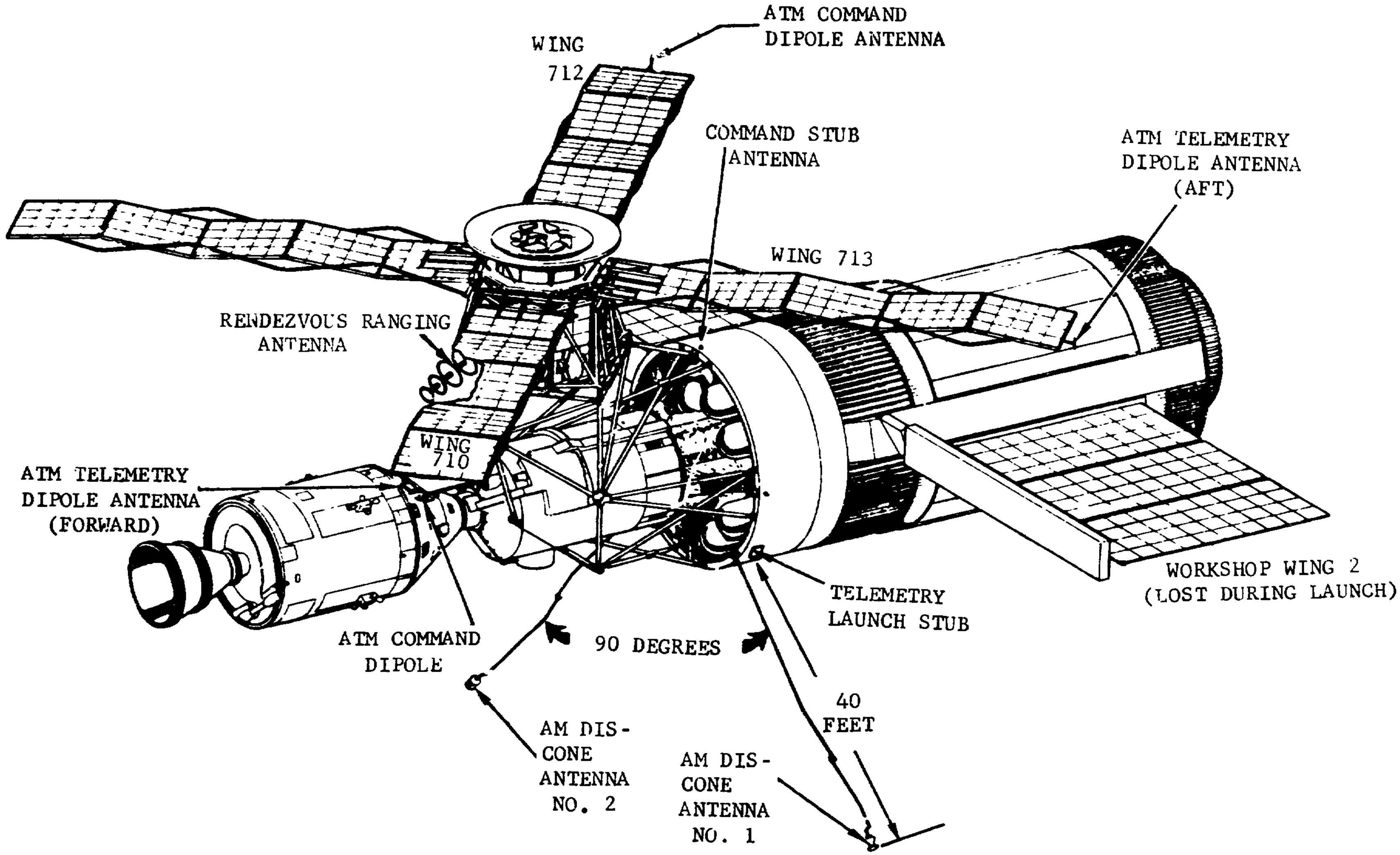


FIGURE 6-2. SKYLAB ANTENNA LOCATIONS

The AM telemetry antenna patterns produce gain levels over 94 percent of each discone's pattern and 93 percent of the stub pattern sufficient to achieve positive RF circuit margins at the STDN receivers, when a 10 watt signal is radiated. For the 2-watt output, the coverage drops to 80 percent for the discones and 68 percent for the stub. AM command antennas provide gain levels over 99 percent of their individual patterns sufficient to yield a positive circuit margin at maximum slant range with typical STDN transmitter levels of 10 kW.

The VHF ranging antenna is located on the ATM support structure in the vicinity between solar wings 710 and 711.

The S-band system of four antennas is located on the CSM, and the four elements are located at 90 degree intervals.

Other antennas are associated with the earth resources experiments or the radio noise burst monitor, and are not part of the I&C subsystem.

b. Link Performance Prediction. In an attempt to quantitatively measure the performance of ATM and AM telemetry links, the original link performance analyses will first be reviewed. In a later section, the actual data indicative of the link performance will be compared to these predictions.

Analyses of telemetry link performance were made for inclusion in premission documentation, and these results are contained in Tables VI-1 and VI-2 for the ATM and AM telemetry links. Antenna gain levels used in the link analysis were associated with a coverage of 75 percent, that is, the antenna gains indicated should be achievable over 75 percent of the individual antenna patterns. Resulting circuit margins are presented for maximum and midrange, 1,300 n mi and 767 n mi, respectively.

Circuit margins associated with midrange distances are considered to be an average measure of link performance, and will be compared to actual performance data.

Using the circuit margins associated with midrange propagation losses, the following average received signal levels result:

ATM Link No. 1	-99.3 dBm
ATM Link No. 2	-95.6 dBm
AM Link B	-95.3 dBm

Adjusting these average levels for the measured ATM transmitter power levels of approximately 13.5 watts for the ATM No. 1 link and 15.5 watts for the ATM No. 2 link yields the following revised average signal strengths:

ATM Link No. 1	-98.0 dBm
ATM Link No. 2	-93.7 dBm

Table VI-1. ATM Telemetry Link Calculations

PARAMETER	FORWARD (WING 710) ANTENNA LINK	AFT (WING 713) ANTENNA LINK
(1) SL Xmtr Power (10 watts)	+40.0 dBm	+40.0 dBm
(2) SL Antenna Gain[1]	-9.0 dB	-5.3 dB
(3) RF Losses	4.5 dB	4.5 dB
(4) Space Losses (Frequency=235.0 MHz, Range=1300 n mi)	147.4 dB	147.4 dB
(5) Receive Circuit Losses (RF and Pointing Error)	2.0 dB	2.0 dB
(6) Ground Station Antenna Gain	+19.0 dB	+19.0 dB
(7) Received Power Level	-103.9 dBm	-100.2 dBm
(8) Receiver System Sensitivity[2]	-107.0 dBm	-107.0 dBm
(9) Carrier Circuit Margin	+3.1 dB	+6.8 dB
(10) Carrier Circuit Margin at Mid-Range (767 n mi)	+7.7 dB	+11.4 dB

1) Antenna gains indicated occur over 75% of the composite RHCP and LHCP patterns.

2) Receiver sensitivity is calculated for a system temperature of 365° Kelvin and a 300 KHz noise bandwidth.

Table VI-2. AM Telemetry Link Calculations

PARAMETER	DISCONE 1 LINK	DISCONE 2 LINK
(1) SL Xmtr Power (10 watts)	+40.0 dBm	+40.0 dBm
(2) SL Antenna Gain[1]	-5.2 dB	-6.1 dB
(3) RF Losses	4.0 dB	3.4 dB
(4) Space Losses (Frequency=235.0 MHz, Range=1300 n mi)	147.4 dB	147.4 dB
(5) Receive Circuit Losses (RF and Pointing Error)	2.0 dB	2.0 dB
(6) Ground Station Antenna Gain	+19.0 dB	+19.0 dB
(7) Received Power Level	-99.6 dBm	-99.9 dBm
(8) Receiver System Sensitivity[2]	-107.0 dBm	-107.0 dBm
(9) Carrier Circuit Margin at Maximum Range (1300 n mi)	+7.4 dB	+7.1 dB
(10) Carrier Circuit Margin at Mid-Range (767 n mi)	+12.0 dB	+11.7 dB

1) Antenna gains indicated occur over 75% of the composite RHCP and LHCP discone patterns.

2) Receiver sensitivity is calculated for a system temperature of 365° Kelvin and a 300 KHz noise bandwidth.

2. RF System Performance.

a. Telemetry Link Performance Data. The performance of ATM and AM telemetry links was monitored during the complete mission. Telemetry receiver automatic gain control (AGC) voltages are recorded at STDN sites during the reception of telemetry, and these AGC voltages are indicative of the RF link received signal levels. These AGC recordings were periodically reviewed for four of the STDN sites, GDS, TEX, MIL, and BDA. The results of these evaluations were both tabulated and plotted.

The tabulations of signal strengths are presented in Appendixes C and D. The signal strength tabulations present link data for groups of 5 to 7 revolutions. For each active link, an average signal level has been estimated from the recordings, and the peak high and low levels experienced during each contact period are also included.

The same data have been plotted in Figures 6-3 through 6-5 for the AM and ATM links, respectively. Data points on these figures represent signal levels received at the four STDN sites as indicated by the small letters adjacent to the data point. Each individual point plotted is an average value of the received signal strength on a specific link over a period between 4 and 7 contacts at a single site. The averaging process smooths over variations due to low elevation passes or short term fluctuations in signal level, and provides a practical method for comparing link performance with premission predictions. This procedure has been followed for both ATM links and the AM-B link. The AM-A and AM-C links were activated periodically, as indicated in Appendix C, but not enough to plot a link history.

Referring once again to the signal strength profiles, a median signal level has been determined for each of the links plotted. The following median levels were determined:

ATM Link No. 1	-97.1 dBm
ATM Link No. 2	-94.5 dBm
AM Link B	-95.8 dBm

These median values compare very favorably with the link predictions indicated previously, and all are within about 1 dB of those predictions.

b. Telemetry Antenna Coverage. The summary of telemetry link performance data presented thus far is also indicative of the mission performance of the antenna systems involved. The closeness of average predicted and actual signal strengths shows, first of all, that under average conditions, both the ATM and AM telemetry antenna systems exhibited levels of gain over 75 percent of their patterns which were sufficient to provide positive circuit margins.

Perhaps the more important conclusion to be drawn from these data is the fact that the antenna range measuring techniques employed in measuring the antenna patterns were probably accurate to within 1 or 2 dB.

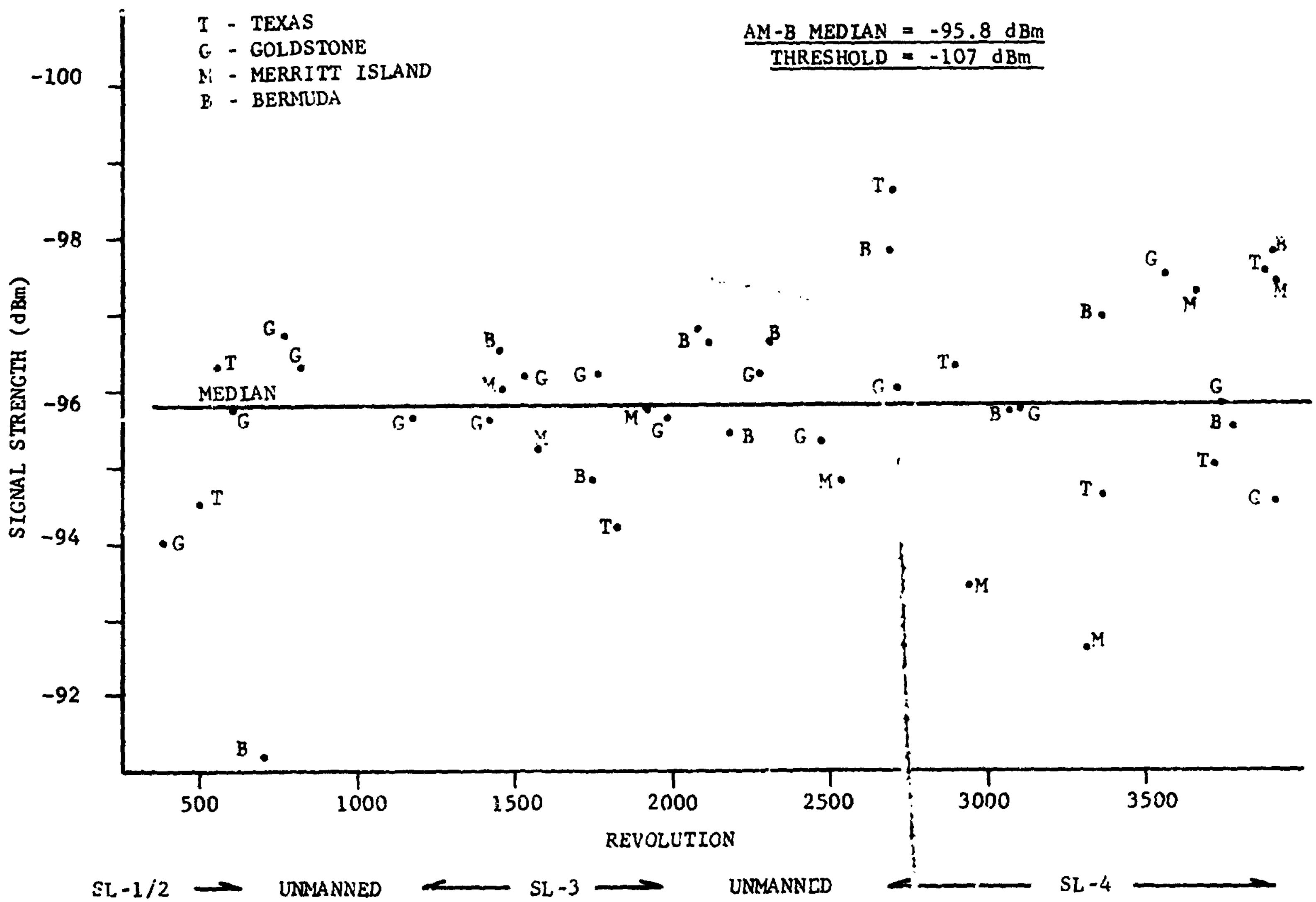


FIGURE 6-3. AM-B TELEMETRY LINK PROFILE

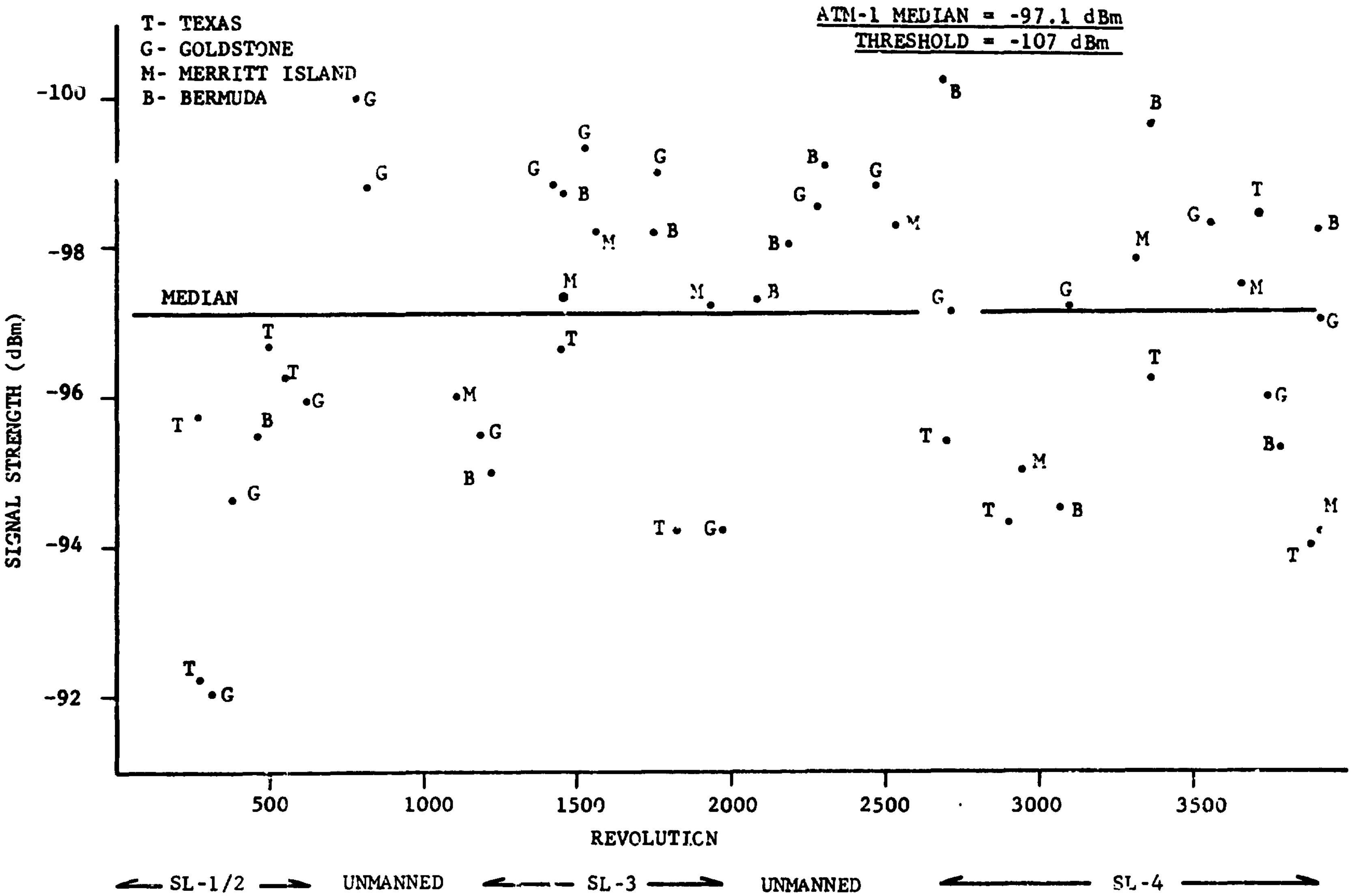


FIGURE 6-4. ATM-1 TELEMETRY LINK PROFILE

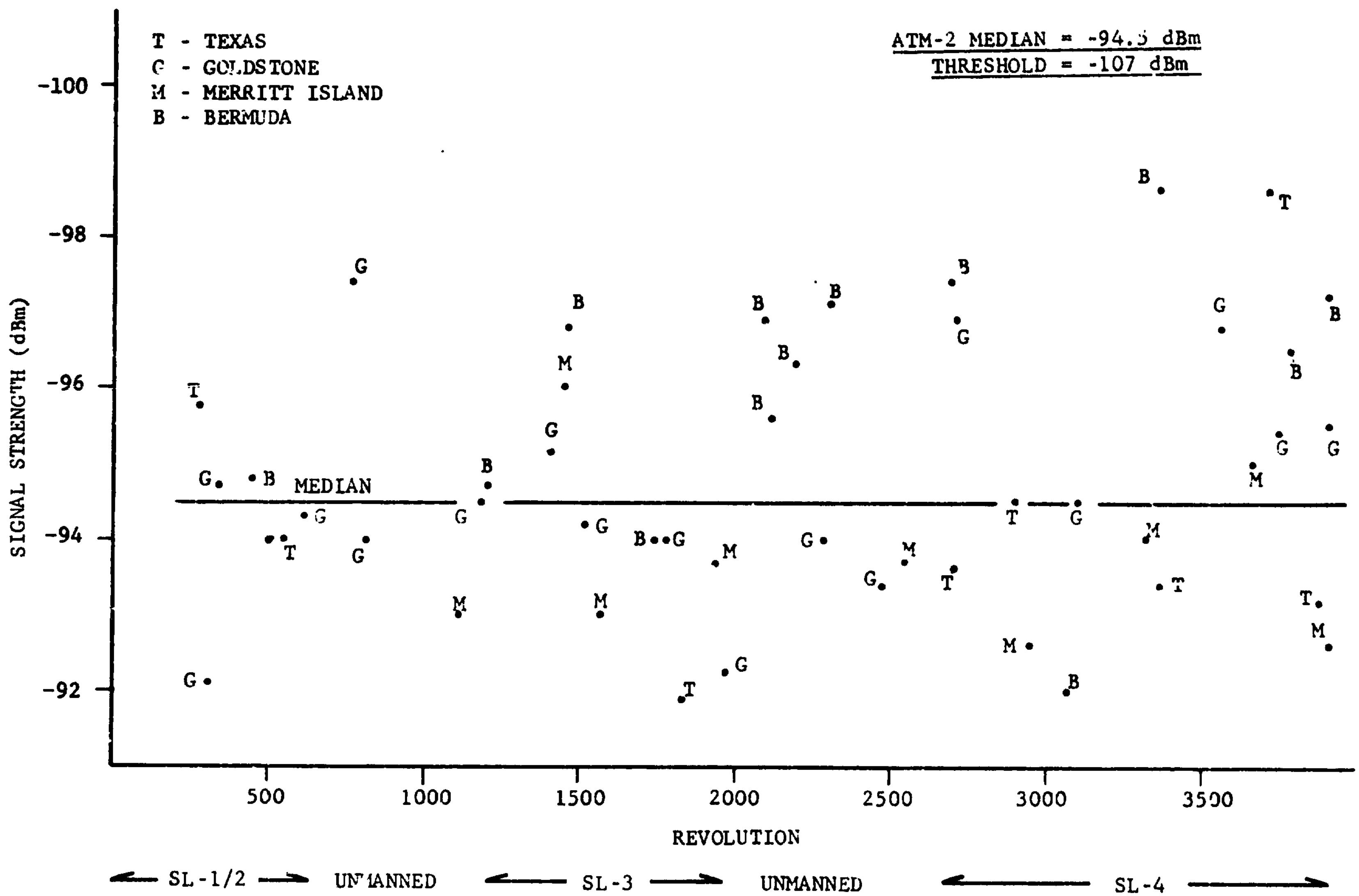


FIGURE 6-5. ATM-2 TELEMETRY LINK PROFILE

The approximately 3-dB difference in median signal levels between the ATM No. 1 and No. 2 links can be explained by referring to antenna pattern data. Available pattern data indicates that antenna gains derived over 70 to 80 percent of the aft ATM antenna exceed the levels derived from the forward ATM antenna by about 3 to 4 dB.

Since the ATM No. 1 link was constrained by early mission events to the forward antenna, and the ATM No. 2 link generally used the aft antenna, it would be expected that link No. 2 average signal levels would be 3 to 4 dB higher than link No. 1. The actual difference over the mission was 3 dB.

Finally, the improved performance of the ATM links, between 1 and 2 dB above predicted levels, may be partially explained by the loss of the SWS solar panel which presented optical blockage to both antennas, and which was simulated in the ground antenna pattern measurements.

c. STDN Tracking Coverage. The Computer Oriented Communications Operational Analysis (COCOA) program was used to generate STDN tracking data throughout the Skylab mission. In addition to STDN sites, data were generated for tracking locations at St. Louis and the Astrionics Laboratory at MSFC. Tracking data were computed for approximately 2-week periods (300 revolutions) and, at each such interval, current Skylab trajectory parameters were used to update the COCOA orbital model. This updating procedure, plus spot checks against other sources of data, insured that the COCOA tracking data maintained a high degree of accuracy.

A summary of tracking data provided for the complete Skylab mission has been compiled to determine the actual coverage provided by the STDN network and also to make a comparison with premission predictions. These figures are tabulated in Table VI-3.

3. <u>End of Mission Status</u>. The telemetry and command links performed their required functions satisfactorily, and at the signal levels predicted. No deterioration in operation was noticeable during the mission, and all links were functioning when the mission was terminated except as noted below. The following paragraphs discuss anomalies that occurred within the I&C subsystem or had a direct impact on the communications functions.

The first of these anomalies concerns the deployment of the thermal shield early in the mission. Since the composition of the shield was reflective to RF energy, it altered the physical contour used to generate the original ATM and AM antenna patterns. As a result, the impact of the shield was twofold. First, it presented a physical blockage over small sectors of the ATM antenna patterns that reduced antenna coverage; and secondly, it distorted antenna patterns previously measured which were used during the mission for antenna selection. Neither of these effects was considered seriously detrimental to ATM antenna coverage. It was estimated that the reduced coverage to the ATM antennas on solar wings 712 (command antenna), 713 (telemetry antenna), and, to a lesser extent, 710 (telemetry and command antenna) was less than 3 percent. The amount

Table VI-3. STDN Tracking Coverage

SL MISSION DURATION 270.90 DAYS

INSERTION-(SL-1) DOY 134 17:39 GMT (1973)

SPLASHDOWN-(SL-4) DOY 39 15:15 GMT (1974)

TRACKING COVERAGE 126 144 MINUTES

(CUMULATIVE NONOVERLAPPING)

PERCENTAGE STDN COVERAGE 32.46%

PREMISSION PREDICTIONS

SL-1/2	33.2 %
SL-3	33.3 %
SL-4	32.75%

SITE CONTACT DATA*

	CONTACT TIME, MINUTES	PERCENT COVERAGE**
VANGUARD SHIP	15 938	12.6
BERMUDA	14 616	11.6
MADRID	13 906	11.0
GOLDSTONE	13 053	10.3
HONEYSUCKLE CREEK	12 293	9.75
MERRITT ISLAND	11 958	9.45
CORPUS CHRISTI	11 658	9.13
CANARY ISLAND	11 056	8.76
CARNARVON	11 028	8.74
HAWAII	10 294	8.15
GUAM	9 018	7.15
ASCENSION ISLAND	8 533	6.75

*Total contact times and percentages exceed mission numbers because of overlapping coverage.

**Percent of mission tracking coverage (126 144 minutes).

of antenna pattern distortion due to reflections from the thermal shield could not practically be estimated because of the multiplicity and randomness of the variables involved; but because of the small sector of spherical coverage involved, it is estimated that this impact was minimal. Because of the location of the discone antennas on the opposite side of the SWS, the antenna sectors affected are a very small part of total spherical coverage, and the amount of reduced coverage was estimated at less than 2 percent. The impact to the launch stub was very similar and considered to be of the same magnitude. Because the command stub is physically located directly under the shield, its coverage impact was estimated to be about 5 to 10 percent.

Shortly after the Skylab launch and insertion, problems were encountered within the ATM communications system when an attempt was made to switch transmitter 1 from the forward to aft antenna, and extremely high reflected power resulted. This eventually led to a mission constraint that transmitter 1 be restricted to the forward antenna; transmitter 2 would continue to be switched between either of the two antennas. It is difficult to quantitatively assess the impact this constraint had on data recovery. Because of the capability to switch the real and delayed-time PCM data between either transmitter, and the need to dump the ATM recorder only about once per revolution, it would seem that any measurable data loss could be avoided at the expense of increased ground management of the ATM system. However, if one assumes that it is essential to recover data over both links for the maximum time possible, the following figures may help to measure the impact of this ATM constraint. With complete freedom in antenna selection, the "effective" or combined coverage of the forward and aft antenna patterns indicates that antenna gains exist over greater than 99 percent of spherical coverage which provide positive circuit margins. Even with the constraint imposed, the data signal assigned to transmitter 2 still exhibits this capability with appropriate antenna control (which may require antenna switching during a pass). However, the transmitter 1 signal only has the available coverage of the forward antenna which provides the required antenna gains over 84.5 percent of its pattern. It must be remembered that these percentages refer to the extent of antenna spherical coverage above a specified gain level, and do not refer to percent of flight time or data volume.

Problems were encountered with the AM communications system on DOY 165 that eventually resulted in the complete loss of the 10 watt telemetry transmitter operating at 230.5 MHz. Operation at this frequency was then switched to a 2 watt transmitter for the duration of the mission.

The reduction in power output from 10 to 2 watts represents a -7 dB impact to the circuit margins for that particular RF link. In order to quantitatively assess the impact of this mode, the link equation can also be viewed as requiring 7 dB higher antenna gains. For the nominal link case, assuming 10 watts of RF power, antenna gains over 95 percent of either discone antenna pattern will provide positive circuit margins at a maximum slant range of 1,300 n mi. The 7 dB higher antenna gains required for the 2-watt power output are achievable over 80 percent of the discore patterns and 68 percent of the launch stub pattern.

Another way of evaluating the impact of the power reduction is to convert the 7 dB factor to a reduced slant range propagation loss, and maintain the high antenna coverage percentages indicated above. This would result in a reduction in maximum slant range from the present 1,300 n mi to about 600 n mi. At slant ranges of 600 n mi or less, antenna gain levels are achievable over 95 percent of the discone patterns that will produce positive circuit margins.

B. Audio System

1. System Description

a. Functional Requirements. The Skylab requirements for the audio system were as follows:

(1) Provide intercommunication capability for three crewmen inside the orbital assembly.

(2) Provide real-time duplex-voice communication between the cresmen within the orbital assembly and the ground.

(3) Provide capability for recording voice and subsequent playback to ground.

(4) Provide duplex-voice communication during EVA between the crewmen, and between the crew and the ground.

(5) Provide data lines to transmit the crewmen's operational biomedical measurements to the data processing system.

(6) Be capable of receiving signals from the Caution and Warning system and route them to the audio stations.

(7) Provide emergency real time voice communication from the SWS to the ground.

Environmental requirements included operation in a 5 psia atmosphere (70% oxygen, 30% nitrogen). The background noise criteria for continuous exposure was established by the Medical Research and Operations Directorate of JSC constraining the acoustic noise profile as noted in Section VI.B.2.a(1).

b. Operational Description

(1) Audio equipment. A block diagram of the complete audio system is shown in Figure 6-6. Salient features of this sytem included:

Two independent audio channels, A and B. The CSM audio and RF communication system was also used by the Skylab for onboard intercommunication and real-time communication with the ground.

Thirteen Speaker Intercom Assemblies (SIA) in the Skylab and one speaker box in the CSM for shirt-sleeve operations.

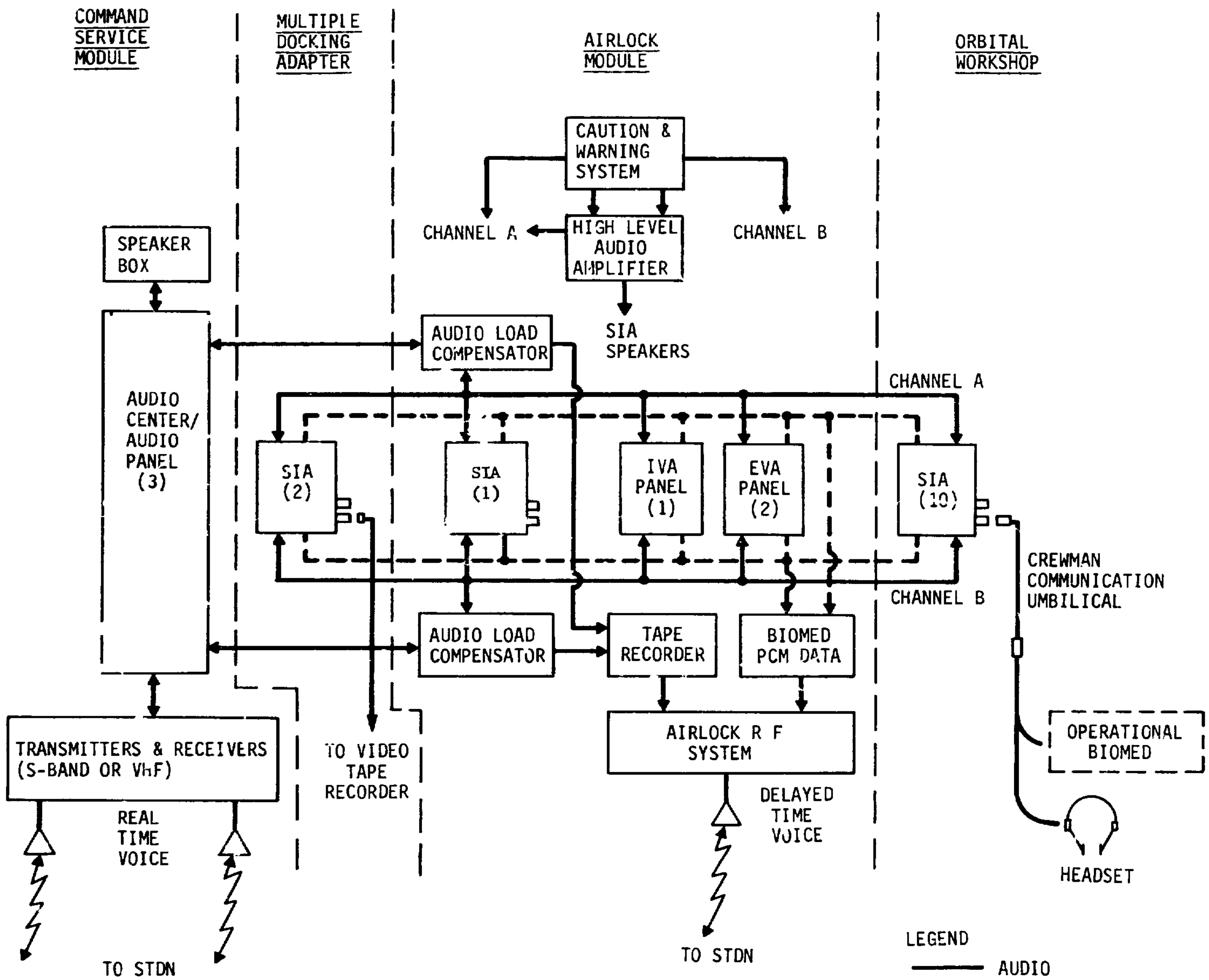


FIGURE 6-6 SKYLAB AUDIO SYSTEM

Two EVA/IVA panels and one IVA panel to support EVA operations.

Onboard voice recording and delayed-time transmission to the STDN was provided by Skylab.

Since the command module for Skylab was existing hardware, the design of the audio system was primarily one of extending these services and capabilities into the MDA/AM/OWS. In support of the Skylab requirements, the CSM had the following capabilities:

Three audio centers (one for each crewman), each capable of amplifying headset microphone and earphone signals operating in a duplex mode.

Capability to interconnect the audio centers in an intercom mode.

Transmit and receive voice signals to and from the STDN via either an S-band or VHF RF link to each audio center.

Voice-operated relay (ON-OFF) communication capability.

Capability to key the transmitter for voice communication with the ground.

The CSM microphone, earphone, and the transmit keying lines that normally interface with the headset assemblies were extended into the AM (see Figure 6-7). The Skylab design consisted of providing an intercommunication system with stations strategically located. A total of 13 SIAs, 2 EVA/IVA panels, and 1 IVA panel were provided inside the MDA/AM/OWS. To provide a proper interface with the CSM, buffer amplifiers in both microphone and earphone lines were incorporated in the AM audio load compensator. This unit also included amplifiers for recording the crewmen's voices. The following is a brief description of the major components of the Skylab intercommunication center.

Speaker Intercom Assembly: The SIA contains a speaker and a microphone operating in a simplex mode. It provides controls for crewmen intercommunication as well as communication with the ground, and provides receptacles for communication umbilicals; contains controls for microphone and transmitter keying, call, channel selection and tape recorder; and provides audible and visual indications from the caution and warning subsystem. The design sensitivity values of the microphone were as follows:

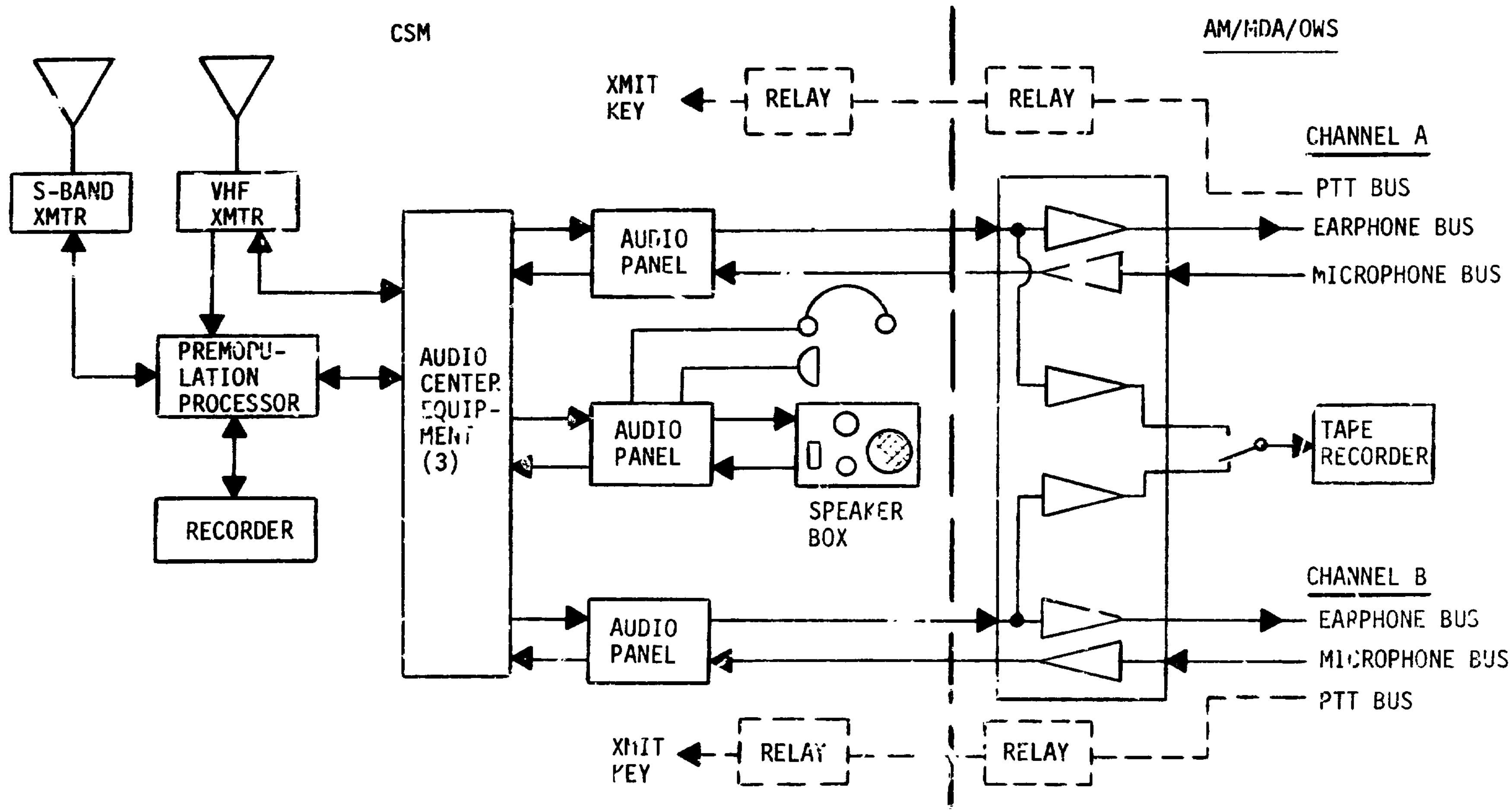


FIGURE 6-7 CSM/MDA/AM/OWS INTERFACE

TRANSDUCER	NOMINAL SPL ON MIC FOR EQUAL OUTPUT	REMARKS
SIA Microphone	80 to 85 dB	Assume the microphone is 6 inches from the lip.
Headset Microphone	102 to 106 dB	Assume the microphone is positioned 1/4 to 3/8 inch from lip.

Crewman Communication Umbilical: The CCU connects the headset and the operational biomedical data to the SIA receptacle. A volume control and a transmitter keying switch are provided as integral parts of the umbilical.

Lightweight CCU: The Lightweight CCU is functionally identical to the CCU except no biomedical wiring is included. A detachable control head containing a volume control and a keying switch is provided allowing two umbilicals to be connected in series.

Communication Carrier Headset: The communication carrier headset contains two microphones/amplifiers and two earphone transducers and can be used for both suited and unsuited operations.

Lightweight Headset: The Lightweight Headset contains only one microphone/amplifier and one earpiece and is used in the shirt-sleeve mode.

Audio Load Compensator: The ALC buffers the CSM Audio Center to the SWS audio distribution bus, provides power amplification, automatic volume control, and isolation for the headset and the microphone lines. Audio inputs to the AM tape recorder are provided.

CSM Audio Panel/Audio Center: The CSM Audio Panel/Audio Center provides the amplification and AGC of microphone signals from the SWS audio channels. Each channel is interconnected to separate audio panel/audio centers. In the intercom privacy mode, the CSM microphone output is further amplified by the earphone amplifier whose output is connected to the SWS ALC earphone circuit. This output signal is controlled by volume controls on the audio panel. Other switches and controls on the audio panel route signals from the second SWS audio channel to the CSM RF system for duplex communications with the ground. The third audio panel/audio center is a backup for Channel A and B in Skylab and is connected to a CSM speaker box whose functions are similar to the SWS SIA.

C2

CSM RF: The CSM RF provides real-time duplex-voice communication with the STDN via either S-band or VHF transceivers. All switching and volume-level controls are located on the CSM audio panel.

The system configuration is shown in Figure 6-8. Pertinent system data are shown in Table VI-4.

Table VI-4. Prelaunch System Characteristics

PARAMETER	DATA	
FREQUENCY RESPONSE MICROPHONE LINE TO EARPHONE LINE	300 Hz (-3.5 dB) 1000 Hz (Reference) 3000 Hz (-3.5 dB)	
NOISE ON EARPHONE LINES	Less than -40 dBm	
CHANNEL TO CHANNEL ISOLATION		
EARPHONE LINES	Less than -41 dBm	
MICROPHONE LINES	Less than -60 dBm	
SIA SPEAKER POWER	5 Watts	
CSM SYSTEM AUTOMATIC GAIN CONTROL	MICROPHONE INPUT	EARPHONE OUTPUT
	-30 dBm	+ 2.6 dBm
	-25 dBm	+ 3.2 dBm
	-20 dBm	+ 8.3 dBm
	-15 dBm	+ 9.3 dBm
	-10 dBm	+ 9.7 dBm
	- 5 dBm	+10.0 dBm
	- 0 dBm	+10.2 dBm
	+ 5 dBm	+10.5 dBm

(2) Interfaces.

(a) Caution and Warning (C&W). Separate C&W tones plus a master alarm light derived from the AM/MDA/OWS C&W system were coupled into each SIA. Activation of the C&W system automatically activated the master alarm light. In addition, the C&W tone would excite the SIA speakers giving a unique aural tone. While no caution tone could activate the speaker if the SIA was powered down, the warning tone was directly coupled to the SIA speaker output transformer bypassing all electronics in the SIA.

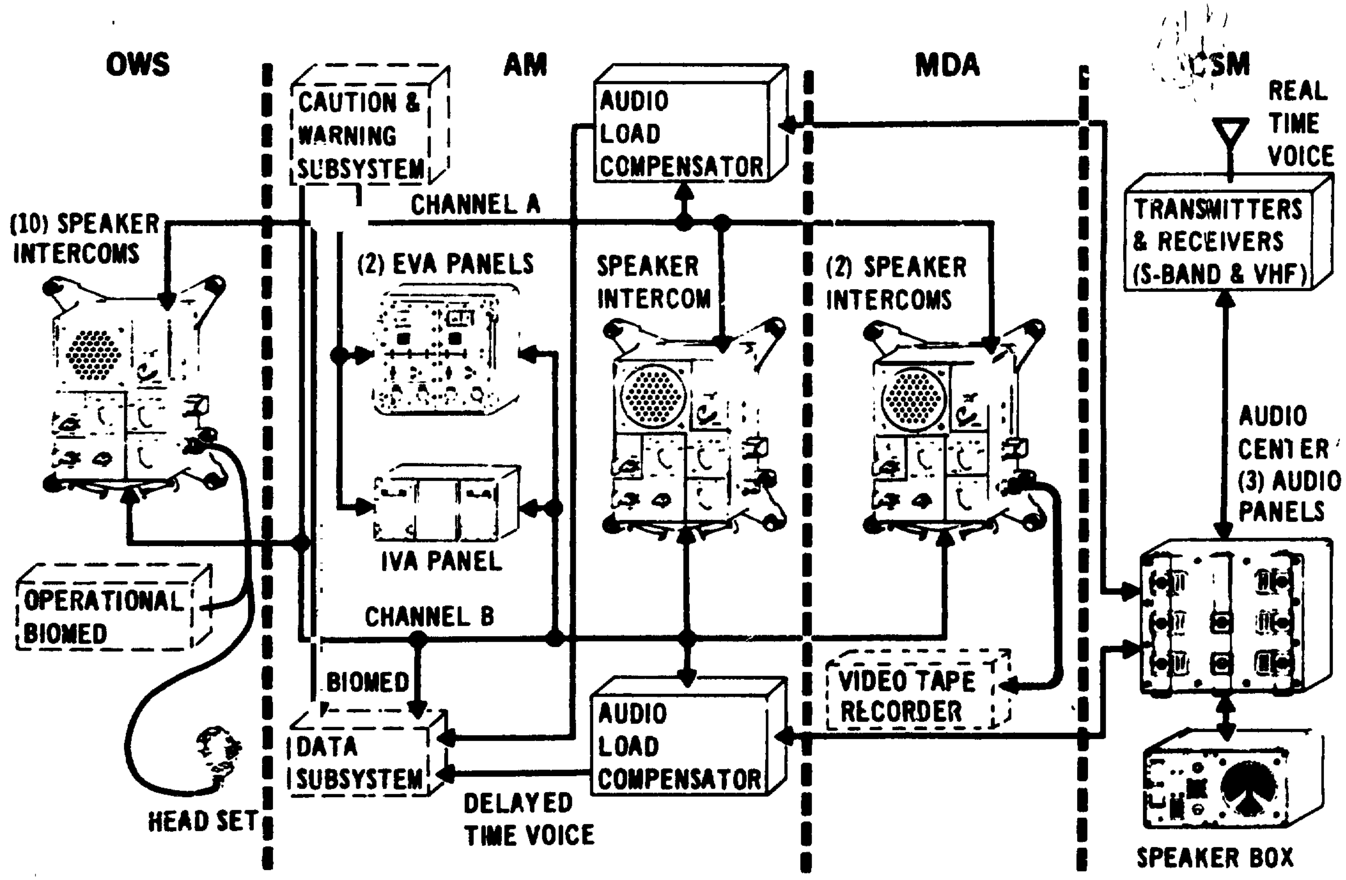


FIGURE 6-8. AUDIO SYSTEM CONFIGURATION

(b) Operational biomedical. The audio system provided the capability to simultaneously route operational biomedical measurements from two astronauts to the AM data system for recording and real-time downlink transmission. Two groups of data lines from the AM PCM system were routed to each SIA and to the EVA panels. Both the EVA electrical umbilical and the crewman's communication umbilical included wiring for transfer of biomedical signals to the data system.

(3) System Operation. Two modes of audio operation were implemented throughout the manned portion of the Skylab mission: One channel was configured for internal intercom and voice communication with the ground via the STDN, while the second channel was used for recording of voice as when annotating an experiment. This data would be dumped when over a STDN station. The above configuration was controlled by proper switch settings at the CSM audio/communication panels and the SWS panels. The mode of channel operation could be reversed by these switches.

Shirt-sleeve communication using the audio system was either via the SIA electronics or via the communication umbilical and headsets. The SIAs were equipped with separate microphone and speaker/amplifier operating in a simplex mode. Switches on the front panel allowed selection of either channel A or B. If the headsets were used, separate cable connectors for channels A and B were available at the sides of each SIA operating in a duplex mode. For EVA activities, the astronaut's life support umbilical (which included the communication and biomedical measurement lines) were interconnected to the EVA panels. During EVA, the CSM voice-operated circuits were activated, providing hands-free operation of the audio system between the crewmen and the ground.

Communication between the Skylab and the ground was dependent on RF contact with the STDN stations. Depending upon the vehicle trajectory, the contact period with the ground varied from approximately 2 to 20 minutes. On average, RF communication with the Skylab was available for approximately 32 percent of the time. Thus, during periods of no contact, any observation, annotation, or comments were tape recorded and the information played back at high speeds when over a ground station.

(4) Crew Interface. Crew interface with the audio system was made possible by the SIAs and headsets. Figure 6-9 is a typical SIA, and it shows the installation locations within the OWS. Controls and monitors on the SIA were as follows:

<u>COMM CHANNEL Switch</u>: Interconnected SIA microphone and speakers to either channel A or B. In the SLEEP position, the amplifiers within the SIA were disabled.

<u>ICOM/XMIT Switch</u>: ICOM activated the microphone circuit of SIA and deactivated speaker circuit of same

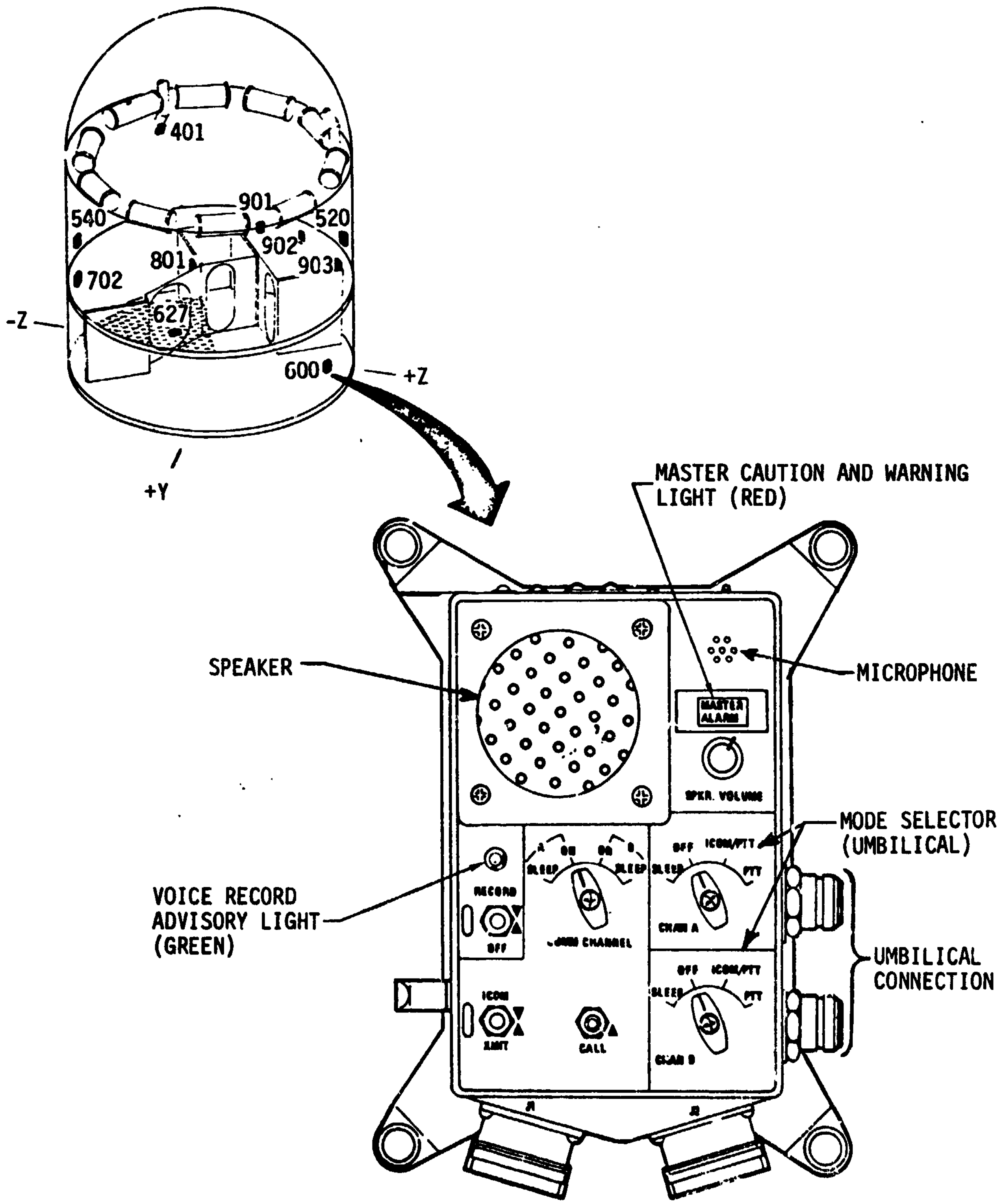


FIGURE 6-9 SIA PANEL AND LOCATIONS IN OWS

SIA (simplex mode). This mode provided intercom capability within the Skylab. The microphone signal was routed to the CSM audio center via the ALC which provided an earphone signal back to all active SIAs or headsets connected to that channel. XMIT provided intercom capability within the Skylab plus enabling the CSM S-band transmitter, allowing real-time voice communication with the STDN.

<u>RECORD/OFF Switch</u>: Controlled the AM tape recorder for voice recording. In the record mode, a green advisory light was enabled on all SIAs indicating voice was being recorded.

<u>CALL switch</u>: Interconnected the microphone lines of Channels A and B, providing voice communication on both channels simultaneously. This switch function was primarily intended for paging and emergency use. If any switch on the SIA was in the SLEEP mode, the CALL signal overrode this position, enabling all SIAs as well as providing voice signals to any interconnected headsets.

<u>CHANNEL A/CHANNEL B UMBILICAL Switch</u>: These switches were associated with each of the adjacent umbilical connectors when the operational biomedical or headsets were used. It controlled DC power as well as providing a HOT MIC capability to the headsets.

<u>UMBILICALS/HEADSETS</u>: Two types of communication umbilicals and headsets were available for shirt-sleeve operation. These are illustrated in Figure 6-10. The communication carrier headset (snoopy hat) provided two microphones and earphones, and while usable in the shirt-sleeve mode it was mandatory for EVA operation because of its redundant components. The lightweight headset provided only one microphone and one earpiece and their use inside the SWS was at the discretion of the crewman.

c. Historical. The following paragraphs present the evolution of design changes that occurred to the audio subsystem as the Skylab program progressed from its initial concept to the final flight configuration. These design changes were necessary to comply with the design requirement revisions that had occurred as the needs of the audio system expanded. The audio system required four major revisions before meeting the final flight configuration requirements.

(1) In 1965, the initial audio subsystem was comprised of a Gemini voice control center, three hardline crewmen umbilical disconnects, and two Gemini VHF voice transceivers, one of which was modified by retuning the receiver. The transmitter in the modified unit

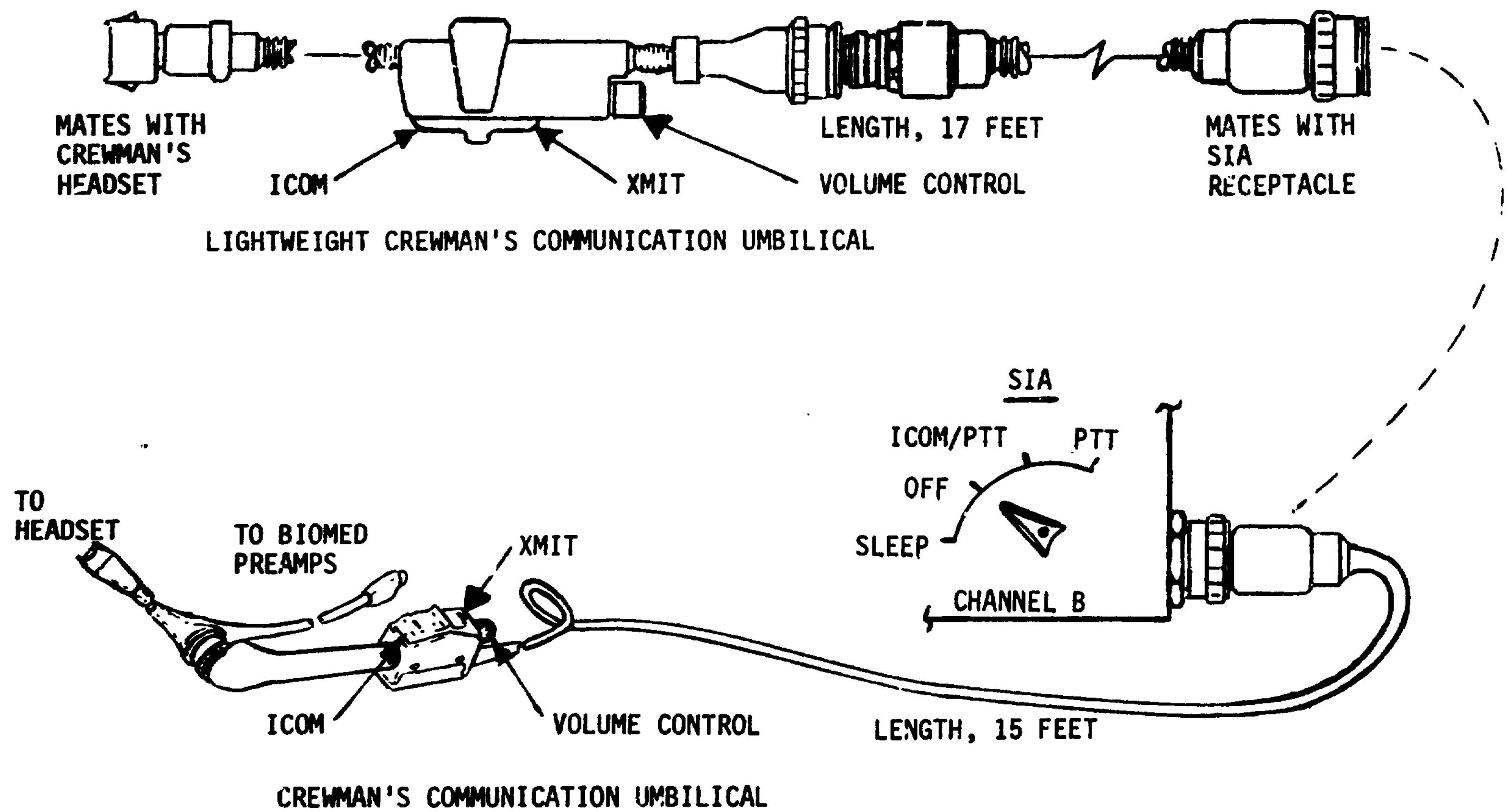


FIGURE 6-10 CREWMAN'S UMBILICAL

was not used. This configuration did not have any audio lines hardwired between the Airlock and the docked CSM. In addition, the crewmen's headset assemblies were to be like Gemini headsets. The umbilical disconnects were to be located in the Airlock forward tunnel and rear tunnel, and were to be interconnected via an audio distribution system to the voice control center that provided the necessary amplification and switching control to provide sidetone, modulation, and reception of the VHF transceivers. The VHF transceivers provided communications between the AM and the docked CSM, and between the AM and the STDN. In addition, the VHF transceivers provided communications between crewmen located in the Airlock and crewmen operating from the proposed EVA portable life support system backpack transceivers.

(2) In 1966, the first major change to the audio system was made by adding an audio control unit and two portable speaker intercom assemblies. The audio control unit was required to provide impedance matching to enable the crewmen to utilize Apollo-type headset assemblies, and to allow the Airlock hardline distribution system to interface with the Apollo audio system. The hardline audio distribution system was expanded to provide crewmen umbilical disconnects throughout the CSM, MDA, AM, and OWS.

The primary voice mode utilized the audio distribution system in conjunction with the Apollo voice communication system to provide communications among the crewmen and between the crewmen and the STDN. The subsystem also included a secondary voice mode which utilized the audio distribution system in conjunction with the Airlock VHF transceivers, voice control center and audio control unit to provide intercom for the crewmen and a VHF simplex link between the Airlock and the STDN. The selection of the primary or secondary voice systems was made by properly positioning jumper cables located in the CSM and AM. A backup voice duplex VHF link was also available which permitted emergency voice communications between the AM and the crewmen using the portable life support system. Two portable speaker intercom assemblies were available and could be connected to any communication disconnect throughout the cluster should headset operation be undesirable.

(3) The second major change in 1967 deleted the Airlock RF voice communication subsystem and added a redundant hardline audio distribution system, two audio load compensators, and three additional speaker intercom assemblies. The deleted equipment included the VHF transceiver, VHF duplex receiver, voice control center, and the audio control unit. Thus, all real-time communication with the ground was to be via the CSM transceivers. This deletion resulted in the incorporation of a redundant audio distribution system, with each connected to a command module audio center. Each audio distribution system included an audio load compensator that provided amplification, isolation, and impedance matching between the SWS and the CSM. In addition, the audio load compensator provided a separate amplified output to allow for modulation of track B of the AM tape recorder to provide voice recording capability. The audio subsystem then included five portable speaker

intercom assemblies that could be connected to any crewman communication disconnect throughout the Skylab.

(4) The third major change to the audio subsystem increased the SIAs from five units to 11 units, installed the SIAs in predetermined permanent locations, and incorporated circuitry within the SIAs to enable interface with the Caution and Warning System; thus providing visual and audible caution and warning alerts. Each SIA provided the capability of selection between Channel A or Channel B, a SLEEP switch to interrupt earphone/speaker audio circuits from a sleeping crewman, a tape recorder enable switch, a call switch to activate all SIA stations regardless of channel selected, and Channel A and Channel B individual crewman communication umbilical disconnects. Incorporation of all these functions in one box resulted from studies and crew preferences.

(5) The final configuration as described in paragraph VI.B.1, increased the SIA quantity from 11 units to 15 units. Thirteen units were to be operational and installed in predetermined locations throughout the SWS in such a manner that any SIA could be replaced with the flight spares.

In addition, program direction required real-time voice capability from the Skylab to the ground, assuming a disabled CSM. An emergency voice kit was developed which provided real-time downlink voice communication with the ground bypassing all audio/RF equipment in the CSM. Uplink communication was to be via the AM teleprinter. The modification kit is described in paragraph VI.B.2.b.(3)(b).

2. System Performance

a. Evaluation of Performance.

(1) Mission Summary. During the Skylab mission the audio system met all objectives and requirements. Ground testing was limited to intermodule tests only, and the on-orbit mating of the CSM of SL-2 with the MDA was the first time that the total audio system was interconnected and operated in a 5 psia atmosphere. The system performed well; and although problems were encountered, redundant components and work-around procedures were implemented imposing no constraints on mission objectives. A chronology of the Skylab audio system timeline is given in Table VI-5.

(a) During the first manned phase, the audio system was first activated on DOY 146. Electrical interconnections between the CSM/MDA were accomplished by the crew without incident. As planned, the Channel A system was configured for general intercom and real-time transmission to ground; Channel B was configured for voice record capability. No significant system problems or hardware failure occurred during this phase of the mission. However, audio feedback

Table VI-5. Audio System Timeline

DATE	MISSION	SYSTEM OPERATION
1973:		
DOY 146	SL-2	SL AUDIO SYSTEM ACTIVATION. AUDIO FEEDBACK OCCURRED PERIODICALLY DURING MISSION.
DOY 173	SL-2	SL AUDIO SYSTEM DEACTIVATED.
DOY 209	SL-3	SL AUDIO SYSTEM REACTIVATED.
DOY 213	SL-3	GARBLED VOICE FROM AM TAPE DUMPS (RECORDER AMPLIFIER FAILURE IN CHANNEL B ALC). ONLY ONE TRA AVAILABLE FOR REST OF MISSION. CHANNEL A, CHANNEL B CONFIGURATION REVERSED; i.e., CHANNEL A - VOICE RECORDING CHANNEL B - INTERCOM AND COMMUNICATION WITH GROUND
DOY 229	SL-3	BROKEN SWITCH ON SIA (REPLACED).
DOY 230	SL-3	HAND-HELD MICROPHONE NOISY - STOWED, AND NOT USED.
DOY 265	SL-3	NOISE OSCILLATION AT 4 Hz HEARD ON CHANNEL B, ASSOCIATED WITH LOSS OF SYSTEM GAIN. PROBLEM DISAPPEARED SAME DAY - SYSTEM RETURNED TO NORMAL.
DOY 268	SL-3	SL AUDIO SYSTEM DEACTIVATED.
DOY 321	SL-4	SL AUDIO SYSTEM REACTIVATED.
DOY 328	SL-4	ANTI-FEEDBACK COMMUNICATION NETWORK INSTALLED.
DOY 333	SL-4	SIA FAILURE STATION 131 (MDA). REPLACED BY ONBOARD SPARE.
1974:		
DOY 019	SL-4	CHANNEL B ALC EARPHONE AMPLIFIER NOISE.
DOY 038	SL-4	SL AUDIO SYSTEM DEACTIVATED.

was heard intermittently during real-time communication with the ground, and the crew indicated that some SIA speakers had to be turned down or the unit turned off to eliminate this problem. Feedback had been observed during the premission altitude chamber tests of the AM/MDA and the SL-2 crew that participated in these tests indicated it could be handled operationally. However, during the mission, most of their time was spent in the OWS where the feedback was apparently worse. This problem is further discussed in paragraph VI.B.2.a.(5).

Because this was the first United States space vehicle which allowed a high degree of astronaut mobility, the use of the umbilical/headset was relegated to special situations such as hands-free voice communication in support of experiments, or in instances where communication was required and an SIA was not accessible. The first crew indicated that when using the audio system the SIAs were used approximately 90 percent of the time.

As mentioned at a crew debriefing, direct communication in the 5 psia atmosphere could be maintained for distances between 5 and 8 feet beyond which the voice level had to be raised or required the use of the audio system. Continuous background octave noise measurements taken in conjunction with Experiment M487 indicated an overall sound pressure level of 56 dB in the OWS and up to 68 dB in the MDA. (See Figures 6-11 and 6-12). In general, the OWS was evaluated as being very quiet. However, because of the Skylab geometry, aural communication could be conducted from the MDA/AM to the OWS by hollering, but required the use of the SIA when communicating in the opposite direction. (Additional details are described in the Skylab Interior Acoustic Environment Report ED-2002-1200-10, Martin Marietta Aerospace, Denver, Colorado. March 31, 1974.)

During the course of this mission, the lightweight headset was often used as a hand-held microphone for annotating a television scene for video tape recording. The resultant voice quality varied depending upon how close the microphone was held to the lips. Therefore, a recommendation was made for a hand-held microphone to be flown on subsequent missions.

During the SL-2 mission and prior to the SL-3 launch, investigations were conducted at the STU-STDN facilities to provide a work-around procedure to eliminate the audio feedback problem. In addition, JSC developed a hand-held microphone for use during the second manned mission.

(b) During the second manned phase, the first audio equipment problem occurred on DOY 213 when playback of the voice received at the STDN was garbled. Checks made on Channel B identified the failure to be the tape recorder amplifier in Channel B of the ALC (see Figure 6-13). This failure in no way degraded the normal intercom loop. Since Channels A and B were identical, the work-around was to reverse the channel configuration whereby Channel B was used for

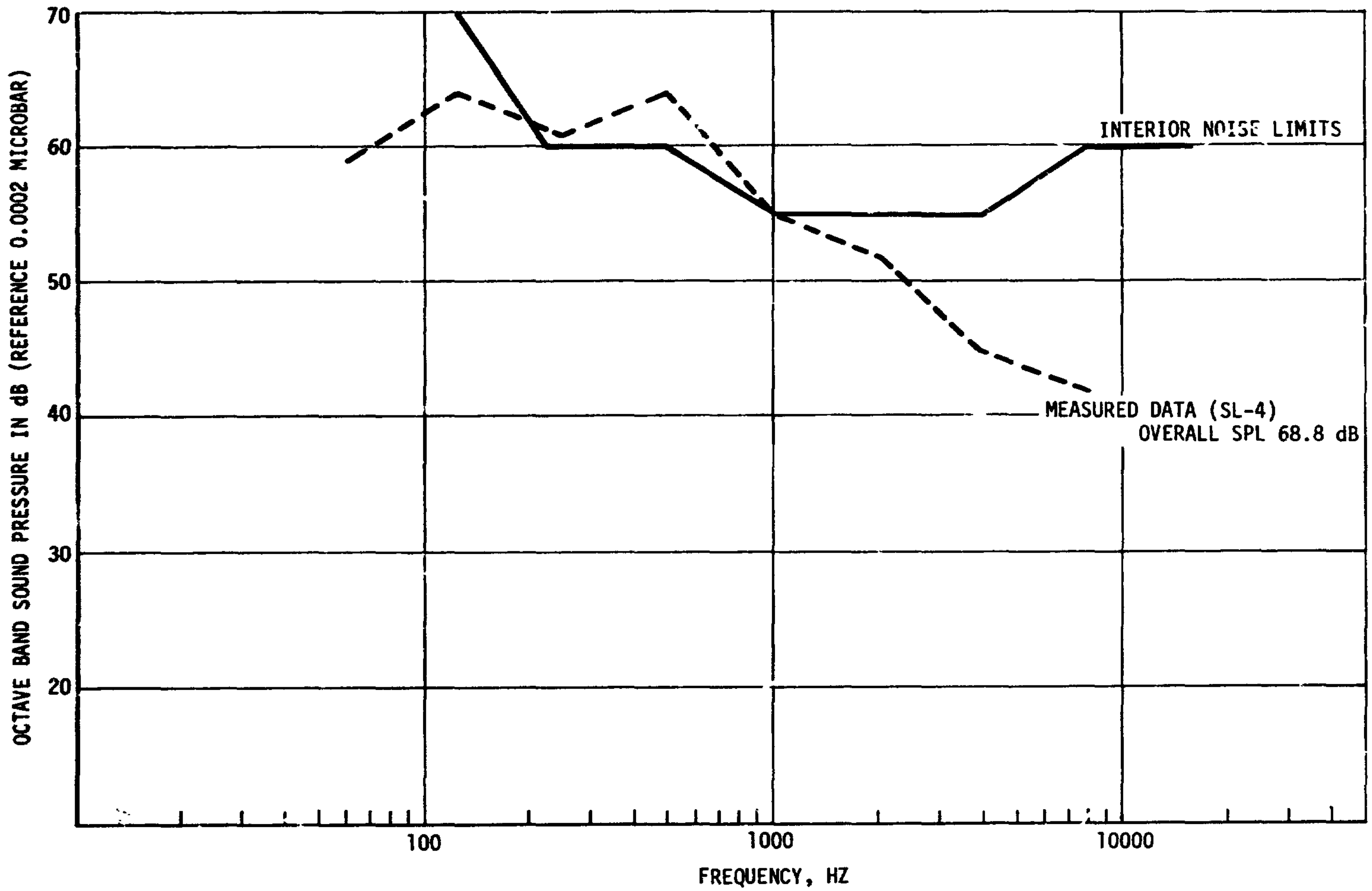


FIGURE 6-11 SOUND PRESSURE LEVEL AT ATM CONTROL AND DISPLAY CONSOLE SIA (EXPERIMENT M487)

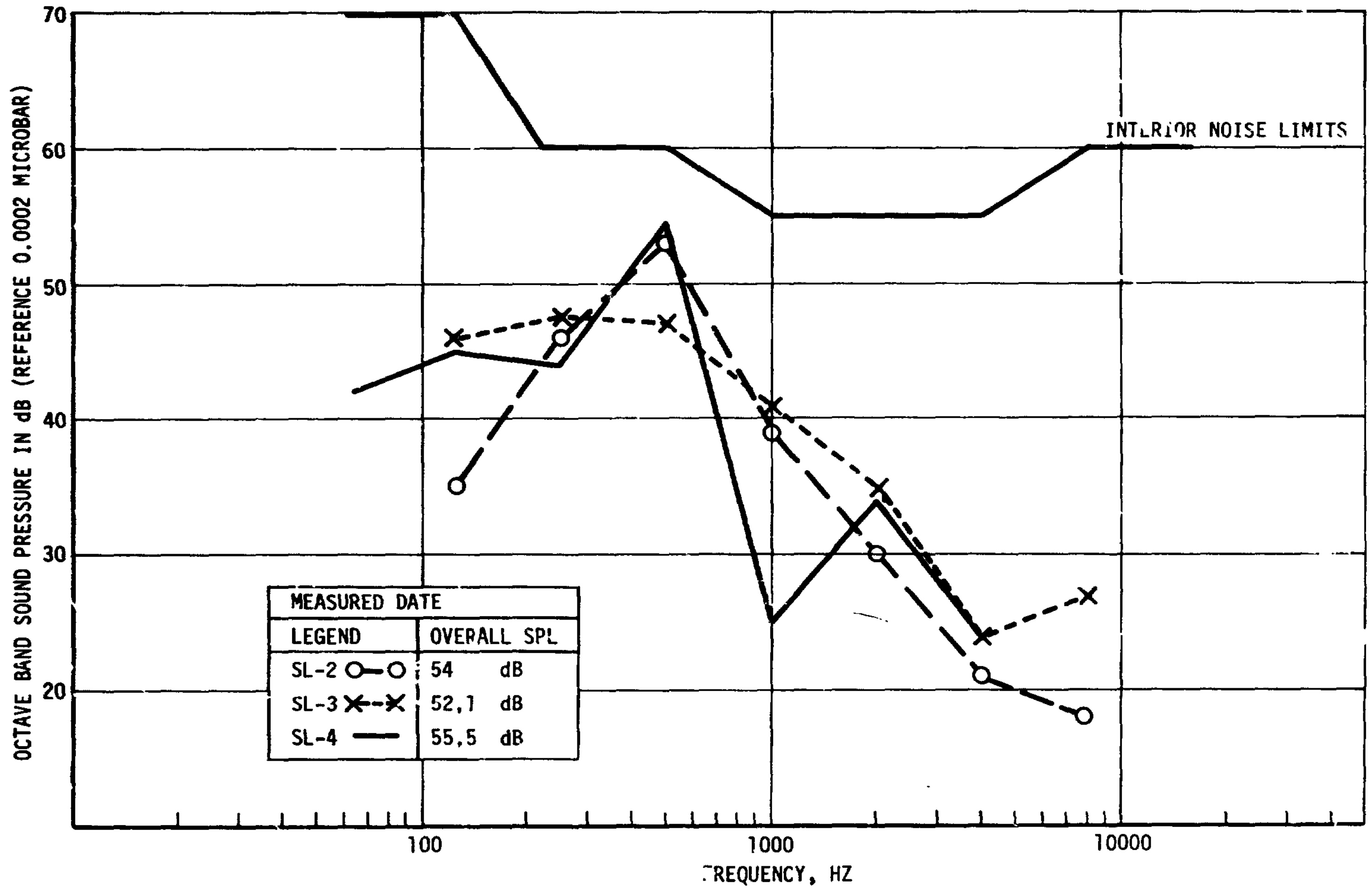


FIGURE 6-12 SOUND PRESSURE LEVEL AT OWS WARDROOM (EXPERIMENT M487)

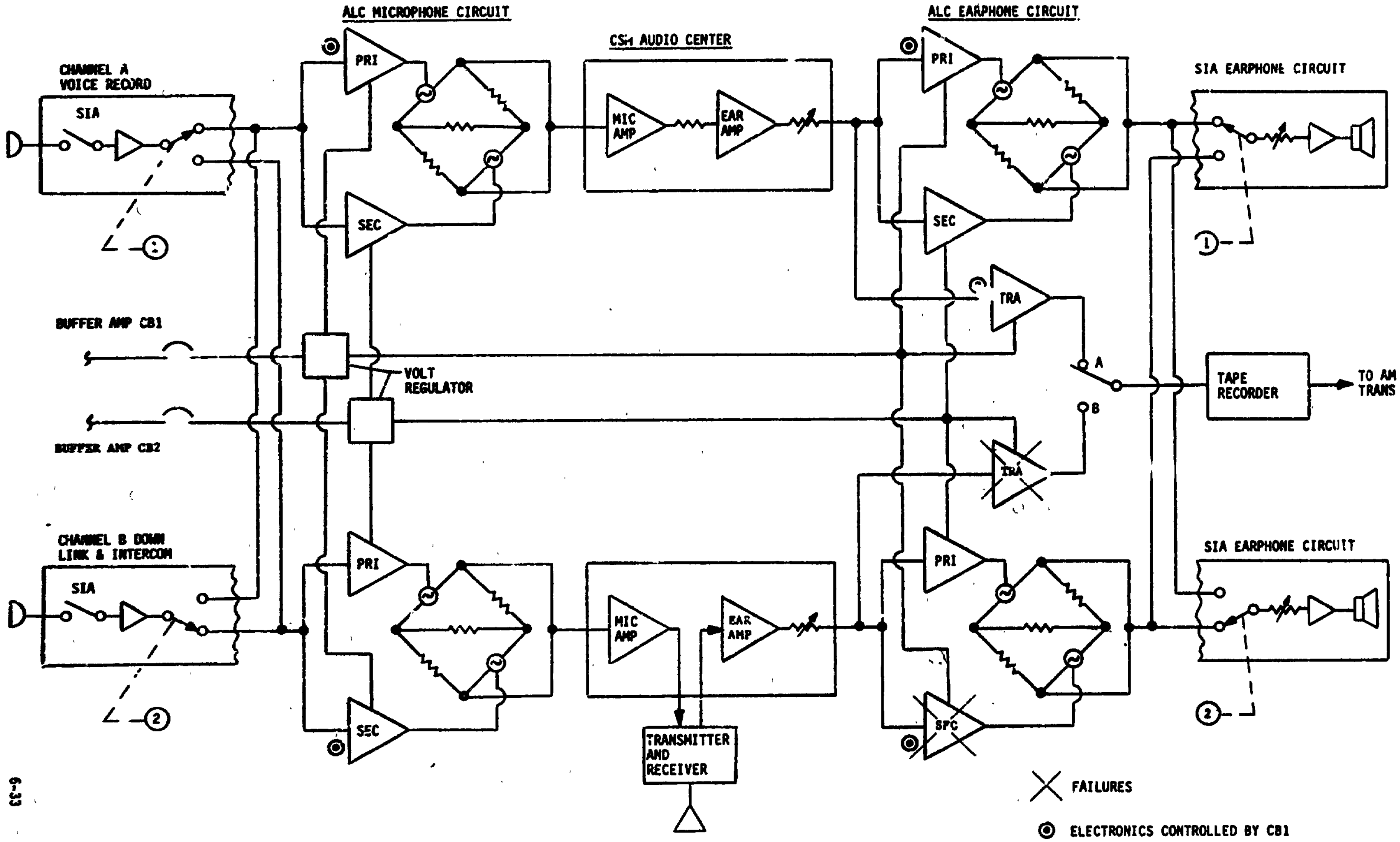


FIGURE 6-13 AUDIO FLOW DIAGRAM - ALC

intercom and downlink while Channel A was used for voice recording (see Anomaly Report No. 213 for additional details).

This procedure returned the system to full capability, but a redundant element in the voice recording system had been lost for the duration of the mission. On DOY 265, noise oscillations occurring at 4 Hz rate were heard on the intercom loop (Channel B) accompanied by a drop in the earphone level. However, communication could be maintained in spite of this anomaly. This discrepancy lasted no more than 1 day, and the Channel B ALC was identified as a possible cause. Following deactivation of Skylab on DOY 268, this same problem manifested itself in the CSM audio system after undocking had occurred. Because of this occurrence the noise problem was attributed to the CSM.

With the loss of a tape recorder amplifier in Channel B of the ALC, the STU-STDN facility investigated the possibility of providing an alternate means of recording voice if the remaining voice record circuit of Channel A should fail during the third manned phase. By analyzing the available electrical connections inside the Skylab, a contingency emergency/voice tape recorder adapter cable was developed as a backup to a Channel A failure and stowed in the CSM for SL-4.

In addition, considerable effort was expended on the ground to reduce the feedback annoyance which was much improved during the second manned phase. The crew devised a procedure of maintaining the wardroom SIA speaker at a high volume and positioning all the other OWS SIA volume controls very low. An antifeedback modification kit, described in paragraph VI.B.2.b(2) was developed.

(c) During the third manned phase with the installation of the antifeedback kit on Channel B, the feedback annoyance was eliminated as long as the SIA speaker volume controls were kept at a reasonable level.

On DOY 332 an SIA failed and was replaced with an onboard spare. On DOY 019 (1974), Channel B experienced noise on the earphone line occurring at a 6 Hz rate. A diagnostic check on the system pinpointed the problem to an earphone amplifier in the ALC. The work-around procedure was to open the audio buffer amplifier circuit breaker (No. 1) providing power to this amplifier (see Figure 6-13). Voice communication could still be maintained in all modes by increasing the volume control in the CSM and the SWS SIAs. However, as noted in Figure 6-13, opening the circuit breaker also disabled the one remaining operational tape recorder amplifier in the ALC. Therefore, for the rest of the mission it was necessary to close the circuit breaker No. 1 only when recording. This procedure did not degrade voice recording since recording was done on Channel A while the noise occurred on Channel B.

(2) Voice Evaluation. This evaluation in this section is primarily subjective since the SWS audio system did not have any telemetered measurements nor were any special intelligibility tests conducted during the mission. Overall evaluation of voice quality compared favorably with premission test and checkout criteria. In spite of the fact that the Skylab could not be tested on the ground as one integral unit, the mission performance did not indicate any additional electrical noise on the line except for those due to equipment failure. No perceptible differences in voice quality could be detected when operating with each of the three CSMs, two of which were never ground tested with the SWS.

(3) Speech/Noise Ratio. Subjective evaluation of the SIA versus the headsets indicated a higher speech/noise signal ratio when using the headsets. This was expected and attributed to the noise cancellation feature built into the headset microphones as well as the higher microphone coupling efficiency inherent with the headset operation (i.e., microphone 1/4 to 1/2 inch from lip). Based on the microphone sensitivity as noted in paragraph VI.B.1.b(1) and the background acoustic data obtained inflight (see Figures 6-11 and 6-12), the acoustic speech/background signal/noise ratio was approximately 28 dB for the SIA and 49 dB for the headsets. The electrical noise of the intercommunication system under normal operation was better than 40 dB below the normal speech level. The background acoustic noise was the primary factor in determining the speech/noise ratio for the SIA, while the system electrical and acoustic noise determined the speech/noise ratio when using the headset.

(4) Voice Tape Recording. Voice was recorded on the analog track of the AM data recorder and was also recorded on the Video Tape Recorder when the television system was operating. The overall quality varied. This variation was primarily due to the coupling efficiency between the microphone and the lip of the crewmen while using the headsets. While the noise cancellation features of the lightweight headset improves the signal-to-noise ratio, it required close positioning between the crew's lip and the microphone.

With the greater mobility available in the Skylab vehicle, it became apparent that the crew required a communication device that could be used without any interconnection to their garment or person. During the mission, the crew was required to record extensive voice commentary. In these situations, the lightweight headset would often be bundled and only the microphone element used. Prior to the second manned phase of the mission, a hand-held microphone was developed by JSC. Although a failure occurred in this microphone, the need for a hand-help, lapel or wireless-type microphone in large vehicles became apparent.

Because of the mission timelines whereby the three crewmen simultaneously performed experiments or tasks which required voice recording, the usage of the voice record channel was such that some annotation or oral briefing could not be recorded.

(5) Feedback. Although feedback was encountered during preflight tests, the degree of feedback during the mission was significantly greater than expected. Feedback on the Skylab vehicle was primarily in the OWS as the MDA/STS volume was small enough that it was not necessary to power up more than one SIA. The location of the SIAs in the vehicle were based on the needs of activation, safety, experiment support, and operational biomedical support. An isometric drawing of SIA locations in the OWS is shown in Figure 6-9.

Audio feedback occurred primarily in the OWS between the SIAs at the wardroom (702), anti-solar scientific airlock, (540), and the one above the ergometer (627). See Figure 6-9. The three units located in the sleep compartments and in the waste management compartment did not cause any operational feedback problem primarily because of low usage, low speaker volume setting, and the relative isolation afforded by the walls in the waste management compartment.

During the AM/MDA 5 psia altitude test, feedback occurred intermittently between the three SIAs in the AM/MDA. However, the crew believed the problem could be controlled during the mission by maintaining configuration control of the SIAs.

At a crew debriefing, the first crew indicated the feedback was worse inflight than during the AM/MDA 5 psia tests. This can probably be attributed to the higher volume control setting required in the OWS and the larger number of SIAs used. Prior to the mission there was no way of assessing the extent of any SIA traffic, such that constraints could be put on their operational usage. As such, these constraints were developed during the mission. A second cause of feedback was the apparent difference in the speaker volume when the system was used in the intercom mode as compared to the PTT mode (transmit-to-ground). This was due to differences in sidetone levels presented to the CSM audio center earphone amplifier that was approximately 5 dB higher in the PTT mode. Thus, an adjustment of the SIA volume controls for satisfactory sidetone volume level during the ICOM mode would result in feedback during an SWS-initiated PTT mode (push-to-talk). Conversely, satisfactory volume level adjustment during the PTT function would result in low sidetone volume levels during the intercom mode.

In evaluating a device to reduce feedback, three areas were investigated: (1) reduce the overall gain of the audio system; (2) provide better equalization in the sidetone level of the intercom and PTT mode; and (3) any modification would have to be easily installed inside the Skylab. The final modification as flown and installed during the third manned phase of the mission is shown in Figure 6-14. This kit modified the system as follows:

(a) The signal on the microphone line to the

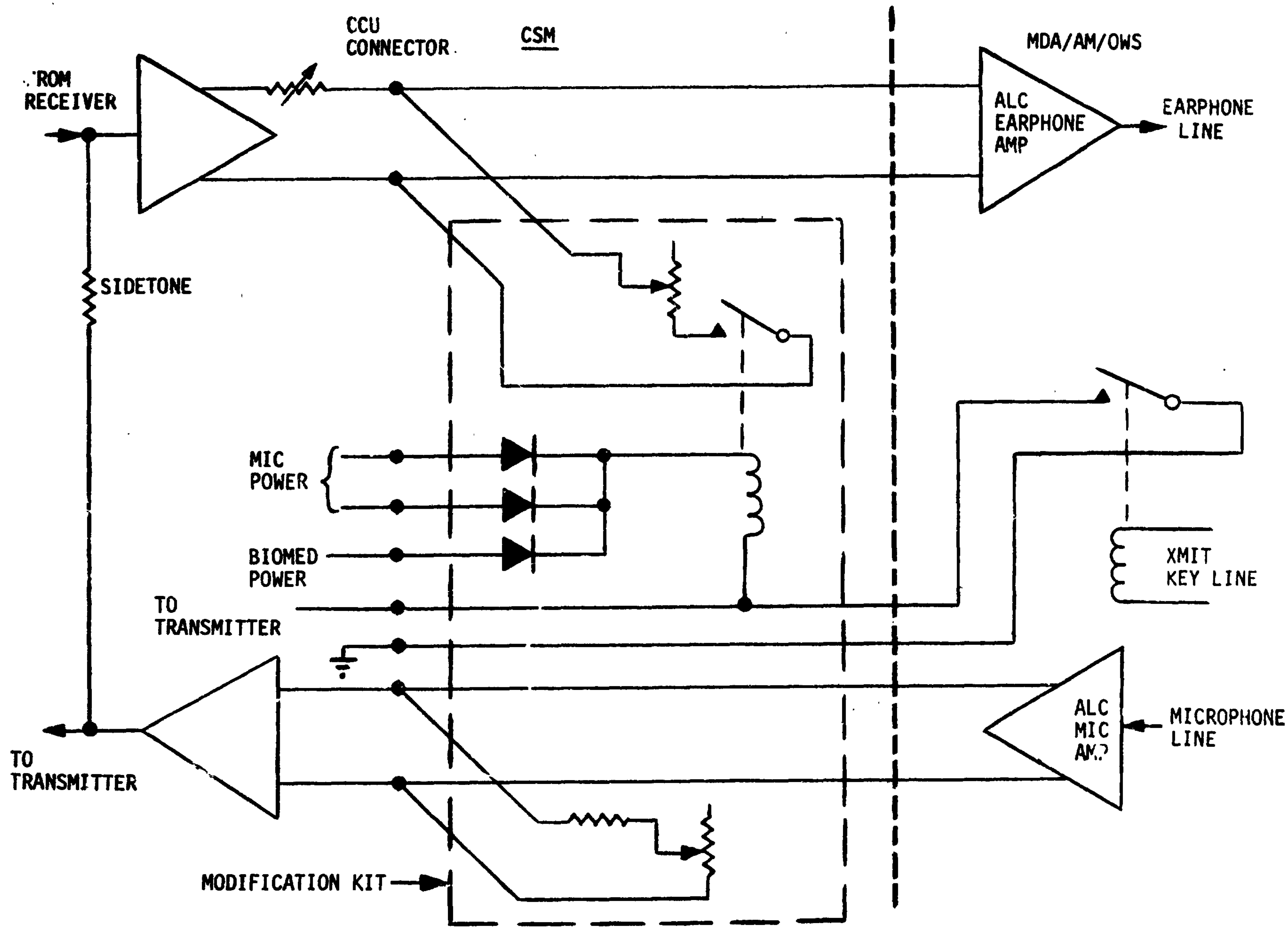


FIGURE 6-14 AUDIO ANTI-FEEDBACK ADAPTER

CSM audio center was reduced by a factor of 11 dB by the insertion of an additional load.

(b) A relay-operated load was installed across the earphone lines between the CSM and the AM which tended to equalize the signal level between the ICOM and PTT modes. This load appeared across the earphone lines only when the PTT switch was energized on any of the SIAs or the communication umbilical. This kit was installed in the CSM and connected to the CSM CCU cable. The impact on the crew was the requirement to place themselves closer to the SIA when modulating the microphone.

(6) Component Evaluation. The SWS audio equipment provided continuous service during the manned portion of the Skylab mission and its design features were such that there were no failures constraining its normal operation. Table VI-6 is a summary of failures that occurred during the mission.

(a) Audio Load Compensator. The redundant design of the audio load compensator was perhaps the most significant factor that kept the system on line and prevented any change in mission planning or crew activities. The ALC, which was located outside the AM, performed satisfactorily during the first manned phase. On DOY 213, the first voice dumps using Channel B resulted in degraded voice at the STDN. It was concluded that the cause was a degraded power supply within the ALC (see Anomaly Report 213). The mission operating time on the equipment was approximately 720 hours.

Noise occurred on Channel B three times during the mission, as noted in Anomaly Report 019-2. These occurrences were on DOY 265, 019, and 022. In addition, the crew reported low volume on Channel B on DOY 212 about the same time as the tape recorder problem previously mentioned. The first noise occurrence lasted about 1-1/2 days; the second discrepancy lasted for 1 day; and the third was continuous until the end of the mission. Although the second occurrence was concluded to be isolated to the CSM (because this noise also was heard after CSM undocking), it is probable that all three noise occurrences and low volume were due to intermittent component degradation in the Channel B of the ALC, that finally failed on DOY 22 (1974).

In the crew alert mode, a command issued from the ground enables the warning tone of the C&W system and activates all SIAs even if they have been turned off. In addition, the SWS earphone lines were paralleled. Thus, no matter what channels the SIAs were switched to, this mode enabled the ground to alert the crew. In this mode, the crew indicated a significant decrease in volume. This low volume resulted because the outputs of two ALC amplifiers were paralleled while the voice signal was amplified by only one. Thus, the second amplifier was acting as a load ($\sim$150 ohms) to the active amplifier.

Table VI-6. Audio System Equipment History

HARDWARE	QUANTITY IN VEHICLE	FAILURES	TYPE FAILURE	MISSION OPERATING HOURS	RELIABILITY	FAILURE DURING DESIGN/TEST
SPEAKER INTERCOM ASSEMBLY	13 OPERATIONAL 2 SPARES	2	1 MECHANICAL (TOGGLE SWITCH); 1 ELECTRICAL (MIC AMP)	N/A	0.77 FOR 8 MONTH MISSION OF 3360 HOURS	ROTARY SWITCH INTERMITTENT. INTERMITTENT MIC LEADS; INTEGRATED CIRCUIT FAILURE IN PRINTED CIRCUIT BOARD.
AUDIO LOAD COMPENSATOR					0.94 FOR 8 MONTH MISSION OF 3360 HOURS	OSCILLATION DURING HIGH TEMP TESTS; TRANSISTOR FAILURE.
MIC AMPLIFIER	4	0				
EARPHONE AMPLIFIER	4	1	6 Hz OSCILLATION	3639		PRINTED CIRCUIT BOARD FAILURE OF INTEGRATED CIRCUIT RESULTING IN NO OUTPUT OR LOW OUTPUT.
TAPE RECORDER AMPLIFIER	2	1	UNINTELLIGIBLE VOICE RECORDING; PROBABLE CAUSE TRA AND POWER SUPPLY	720		
LIGHTWEIGHT UMBILICAL AND CONTROL HEAD	8	0	NONE	N/A		
CREWMAN COMMUNICATION UMBILICAL	3	0	NONE	N/A		

(b) Speaker Intercom Assembly. The SIA provided reliable service for the multiple tasks of intercommunication, voice recording, headset operation, biomedical data line interface, and C&W indicators. Because there were no cable constraints, the SIA was the preferred mode of voice communication as compared to the headsets, and used 90 percent of the communication time. See Anomaly Reports 229 and 332 for problems resulting in replacement with spare units.

Crew evaluation of the SIAs was as follows:

The SIA locations, in general, were satisfactory; however, SIA No. 600 was not required, while SIA No. 627 could have been better located within the experiment compartment.

The type of functions on the SIA was satisfactory.

The microdot connector (used with headset umbilicals) performed satisfactorily with no bent pin problems as experienced on the ground. However, the alignment marks on the connectors had to be in line for satisfactory interconnection.

The Zero-G connectors which interconnected the SIAs to the Skylab audio system performed satisfactorily but were not as easy to mate as the microdot connectors.

The SIA volume level and quality were adequate.

A more positive means of indicating whether an SIA was in the intercommunication mode or air-to-ground mode should have been provided.

The inability to swivel the SIAs, or relocate them, was a nuisance.

With no UP or DOWN orientation in the Skylab, the operation of the ICOM/PTT switch (a momentary three-position, return-to-center, toggle switch) was confusing because one position would be mistaken for the other and the crew operated this switch from different angles. This was especially true of SIA (627) which was mounted with its front panel facing the floor of the experiment compartment.

(7) Caution and Warning and Biomedical Interface Evaluation. The C&W and biomedical interfaces performed as designed and no problems were encountered during the entire mission. The biomedical interface at each SIA provided DC power to the operational

biomedical signal conditioners, as well as the capability to process four channels of biomedical measurements plus the crewman's identification signal. The most significant factor regarding these channels was that since biomedical monitoring was not continuous, these channels were also time shared with experiments approved late in the Skylab program with no additional modification to the data system.

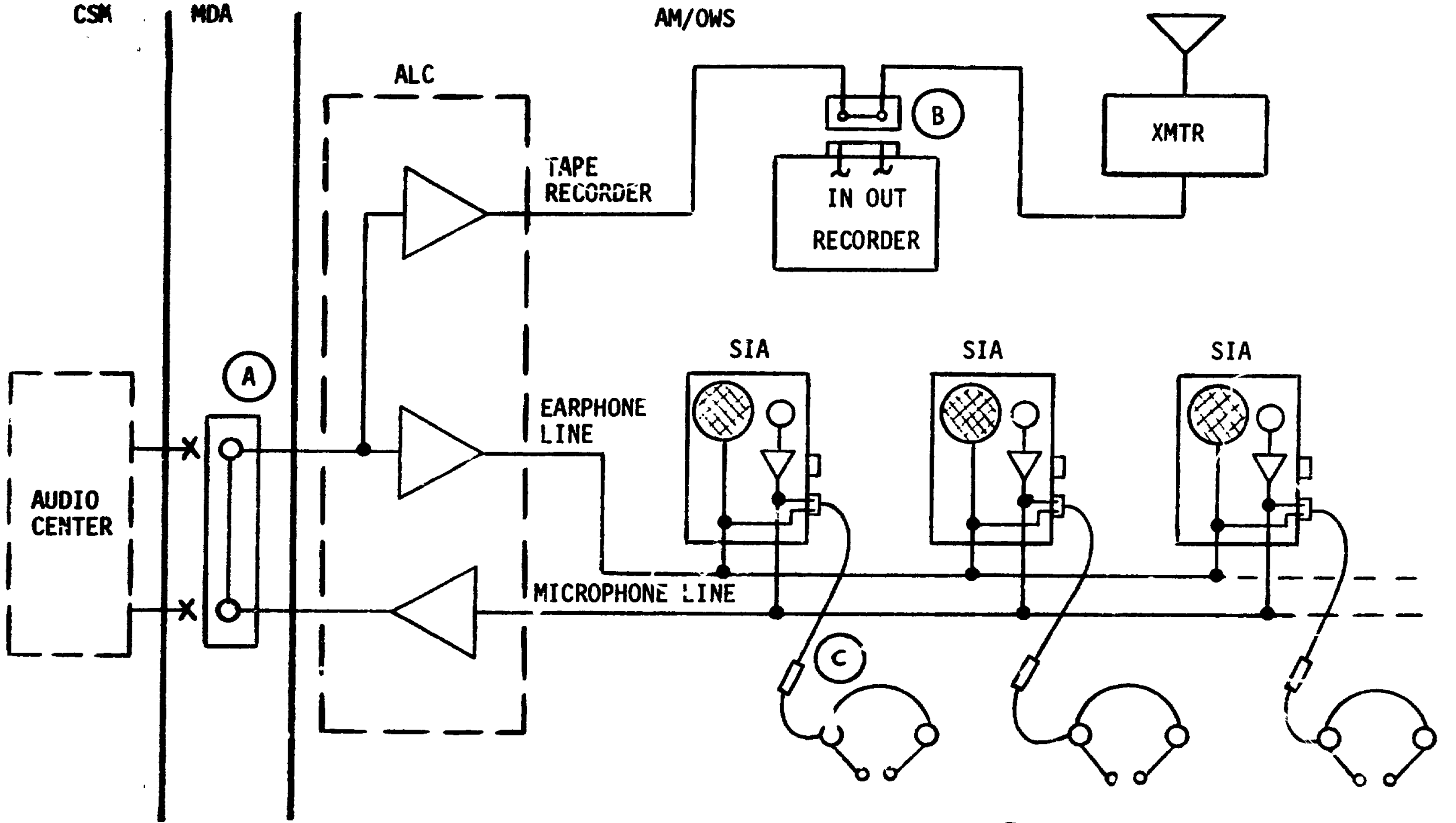
b. Inflight Support of Equipment.

(1) Skylab Rescue Kit. An audio kit was stowed aboard the Skylab-1, which was to be implemented should a catastrophic failure occur in the CSM. This would require the launch of a rescue CSM. Assuming a complete loss of the CSM electronics, three types of connector adapters were to be installed by the crew providing onboard intercom and real-time downlink transmission voice, as shown in Figure 6-15. Uplink communication was to be via the teleprinter. The installation of the MDA shorting plug (A) coupled the ALC microphone amplifier output to the inputs of the earphone and tape recorder amplifiers in the ALC. Since the voice input and output wiring of the AM tape recorder was in the same connector, shorting plug (B) bypassed the voice signal around the tape recorder and allowed direct modulation of an AM 10-watt transmitter. All connectors were accessible within the Skylab.

Coupling of the microphone and earphone amplifiers also provided onboard intercommunication capability. Prelaunch tests indicated low volume when using the headsets due to bypassing of the CSM audio equipment. Since the Communication Carrier headset had a second microphone output 8 dB higher than the one normally used, a simple inline adapter (C) was provided for installation on the umbilical lines, cross-wiring the microphone line to this higher output. This kit was not implemented during the mission.

(2) Audio Antifeedback Modification Kit. In order to reduce the feedback prevalent during the first and second manned phases, an antifeedback network assembly was installed during the third manned phase. A block diagram is shown in Figure 6-14. The microphone signal to the CSM was desensitized by padding the line for an 11 dB signal attenuation. As noted on the AGC curve of Figure 6-16, attenuating the voice input by 11 dB shifted the normal operating range towards the knee of the curve. Decreasing the input to the CSM audio center also shifted the unvoiced microphone input away from the effects of the AGC action.

Different sidetone circuits were applied to the system when operating in the intercom and transmit-to-ground modes. When the SIA switch was depressed to XMIT, the sidetone was approximately 5 dB higher than when pressed to ICOM. In order to equalize these levels, a relay-operated load was inserted across the earphone lines from the CSM to the AM ALC only when the SIA switch was depressed to the XMIT mode. This was accomplished by connecting the ground side of the relay to the PTT ground line that, in turn, was controlled by the SIA



NOTE: RESCUE MODE UP-LINK COMMUNICATION IS VIA TELEPRINTER

(A) MDA SHORTING PLUG

(B) AM SHORTING PLUG

(C) HEADSET FILTER BYPASS ADAPTER

FIGURE 6-15 SKYLAB RESCUE MODE AUDIO CONFIGURATION

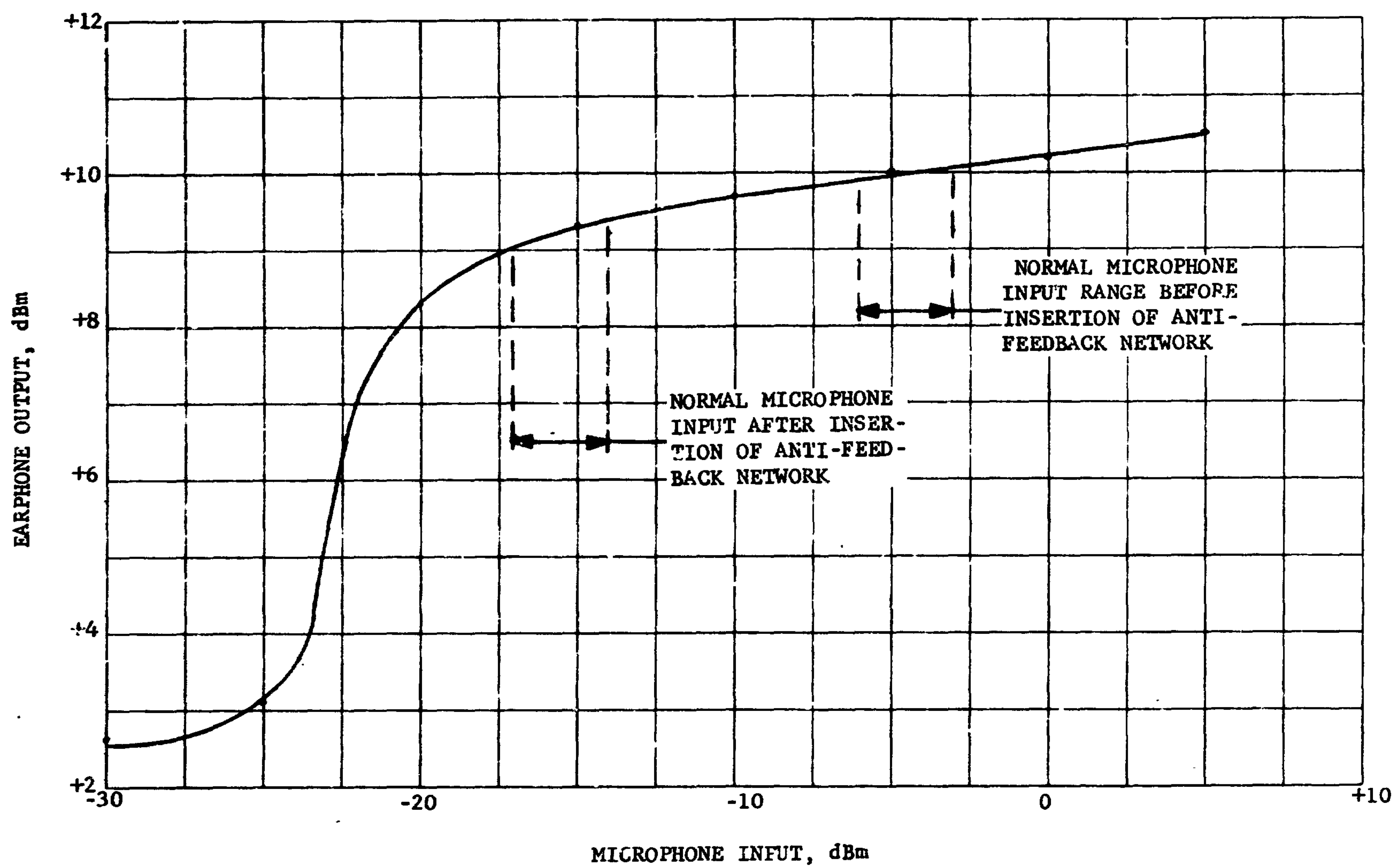


FIGURE 6-16. CSM AUDIO CENTER AUTOMATIC GAIN CONTROL

XMIT switch. This kit was connected to the communication umbilical in the CSM where all of the required interconnecting points were available.

(3) Recorder/Audio Load Compensator Bypass Cable. A modification kit consisting of a four-connector cable assembly was developed and flown on the third manned phase as a backup to the one operational tape recorder amplifier in the ALC. One of two recorder amplifiers failed on DOY 213. Since the loss of this amplifier reduced redundancy and recording capability, an added capability of providing emergency real-time voice downlink via the AM transmitter was provided as follows:

(a) Direct Voice Record. This mode provided the capability to couple the microphone output of any SIA directly into a tape recorder (see Figure 6-17a). This was accomplished by connecting the lightweight communication umbilical to the SIA and interconnecting the bypass cable from this umbilical to the tape recorder. The third connector on this bypass cable was connected to the cable that was normally connected to the tape recorder. This configuration provides voice and data record capability and playback into the AM transmitters. Tape recorder playback yielded transmitter deviations between 35 and 140 kHz with satisfactory signal-to-noise ratio.

(b) Emergency Real-Time Voice. The emergency real-time voice configuration is shown in Figure 6-17b. In this mode the cable containing the wiring from the tape recorder to the transmitter was removed and connected to one end of the adapter cable (P2). Connector P1 of the adapter cable was connected to the SIA microphone lines using an onboard lightweight communication cable. Tests conducted on the ground indicated transmitter peak deviations between 35 to 200 kHz depending upon the microphone used and speaker-microphone displacement.

3. <u>End of Mission Configuration</u>

a. Equipment. Compared to the system when first activated on Skylab, the status of the audio system prior to deactivation at the end of the Skylab mission was as follows:

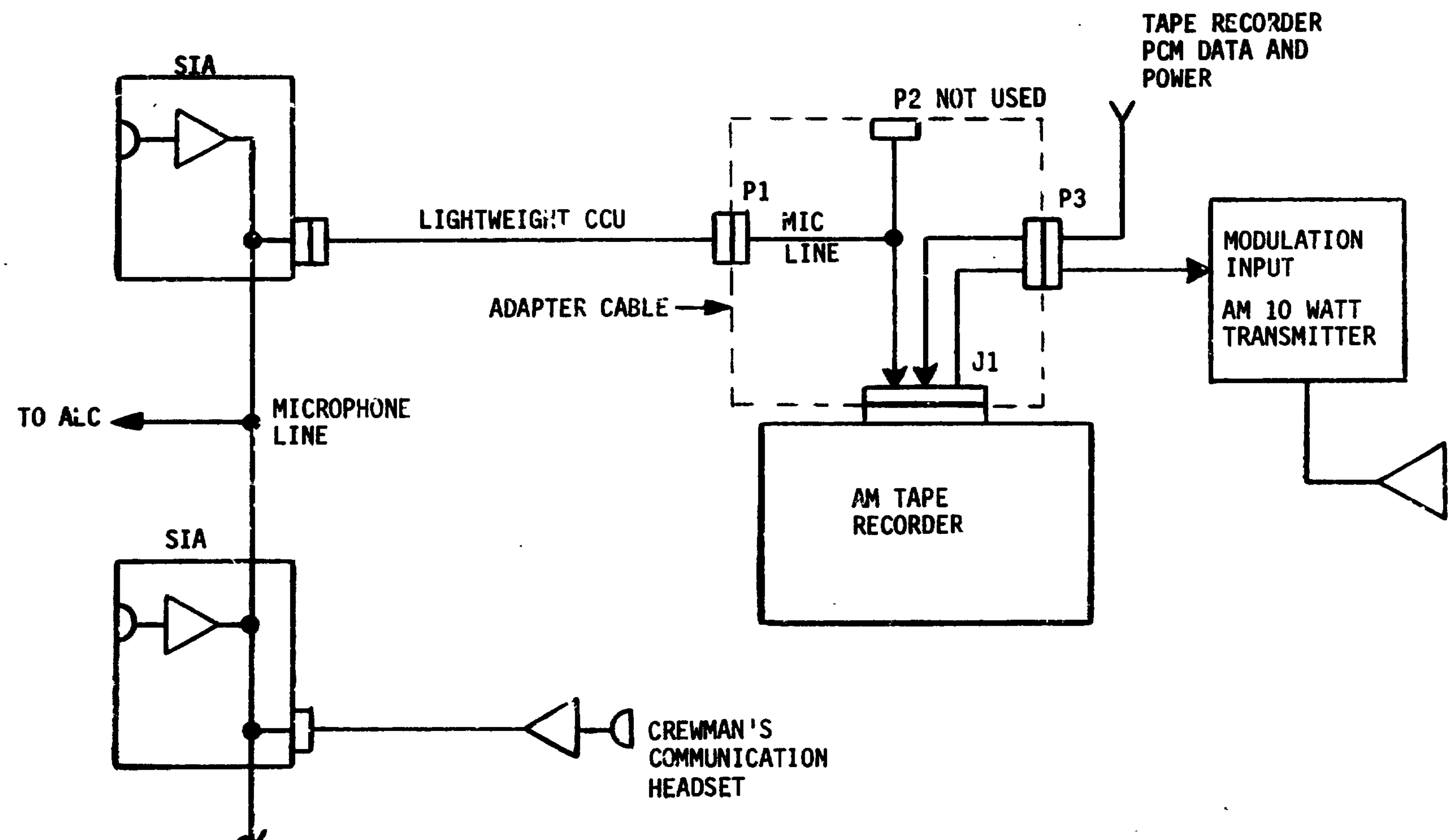
(1) One of two tape recorder amplifiers was operating.

(2) One of two earphone amplifiers in the Channel B of the ALC was operating.

(3) All SIA stations were active.

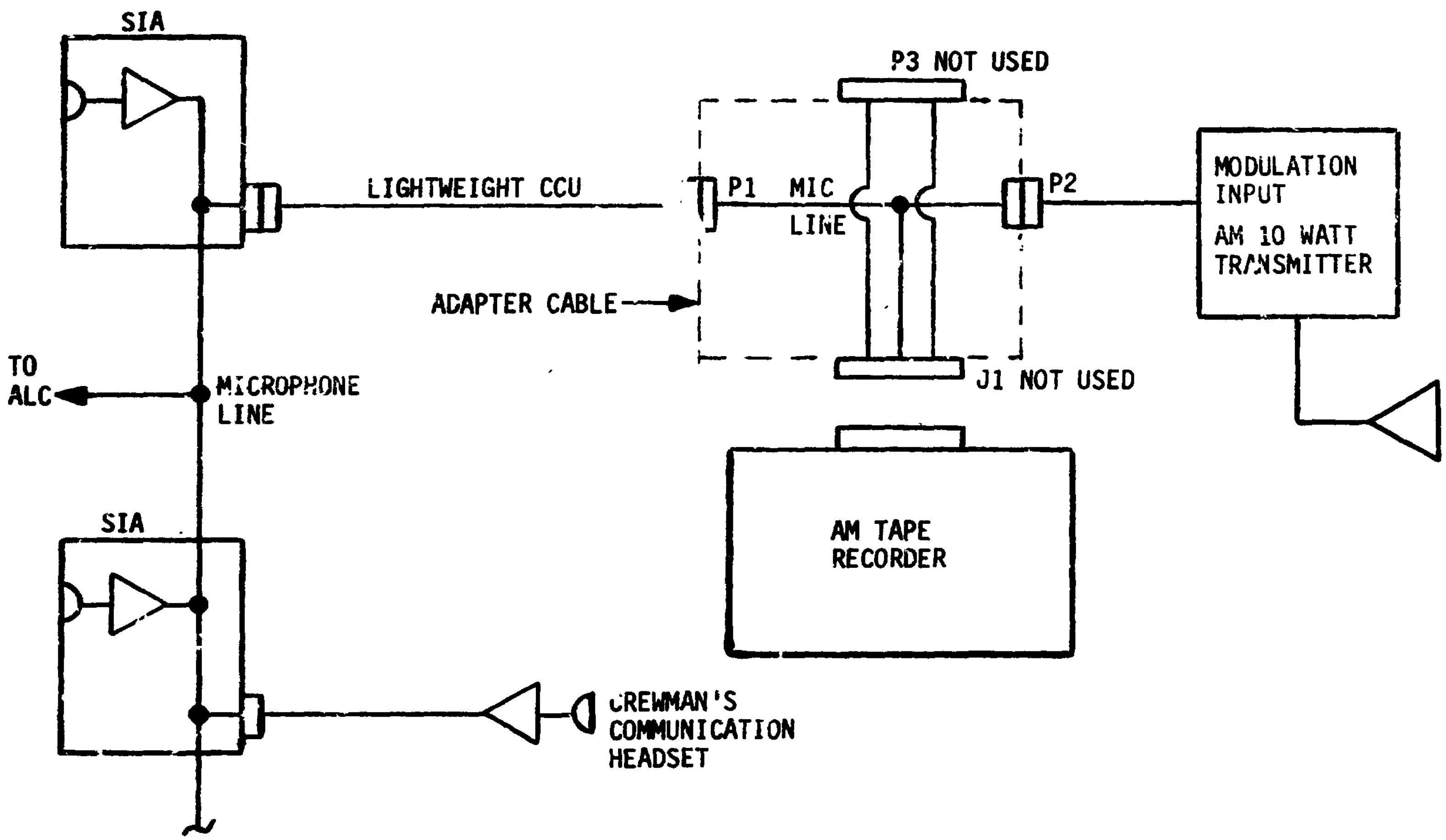
(4) An antifeedback network assembly was installed on the air-to-ground channel.

(5) A recorder/ALC bypass cable was designed and stowed on Skylab for backup capability.



INSTALLATION FOR AUDIO TAPE RECORDING

FIGURE 6-17a EMERGENCY TAPE RECORDER VOICE CABLE ASSEMBLY



INSTALLATION FOR EMERGENCY VOICE DOWNLINK

FIGURE 6-17b EMERGENCY TAPE RECORDER VOICE CABLE ASSEMBLY

b. System Status and Constraints. Prior to deactivation, the air-to-ground channel was operating satisfactorily, especially with the installation of the antifeedback network. However, the oscillation of an ALC earphone amplifier on the voice record channel required opening of a circuit breaker to disable the amplifier. Any time voice recording was required, this circuit breaker was closed and the oscillations were tolerated by the crew.

C. Television System

1. System Description

a. Functional Requirements. The salient function requirements of the Television (TV) system are as follows:

Transmit real-time or delayed-time video to the STDN when the CSM is docked and real-time video when the CSM is undocked. All video transmissions are through the CSM unified S-band link which has a bandwidth of 0 to 2 MHz.

Provide video data from the ATM experiment cameras and a portable color camera. Interior viewing is provided by crew use of the portable camera throughout the habitable area. External viewing is provided by connection of the portable camera in the AM, attachment to the experiment T027 extension boom, or by attachment to the experiment S191 optical adapter.

Delayed-time composite video/audio is provided by a VTR located in the MDA.

All camera output formats are as defined in EIA Standard RS170, except the portable camera has a video-to-sync amplitude ratio of 100:28 with NTSC color line and field rate, and the ATM cameras have an aspect ratio of 1:1.

Distribution, selection, and signal conditioning elements in Skylab have a frequency response, referenced to 500 kHz, as follows:

SIGNAL	2 MHz REAL-TIME	4 MHz REAL-TIME	2 MHz RECORDED PLAYBACK	2 MHz RECORDED PLAYBACK
MDA/AM/OWS	±3.0 dB	+3.0 dB -3.55 dB	+3.0 dB -3.75 dB	+3.0 dB -4.8 dB
ATM-1	-2.67 dB	-4.55 dB	-3.42 dB	-6.05 dB
ATM-2	-3.26 dB	-5.53 dB	-4.01 dB	-7.03 dB

In the CSM, these elements have a frequency response of plus or minus 3 dB from DC to 4 MHz.

The portable camera is capable of operating with natural and artificial scene illumination in the range of 5 to 10,000 foot-candles.

Interior average ambient illumination of the Skylab is a minimum of 4.5 foot-candles.

The STU/STDN was required to functionally simulate the TV airborne and ground systems using flight-type hardware, except that bulkhead feed-through connectors were omitted, and only one ATM camera video channel and functional TVIS was implemented. The facility was required to support the mission through performance of anomaly testing, crew procedure preparation, and video data evaluation.

Detailed utilization of the TV system was defined in the Mission Requirements Document and the TV Operations Book as published for each manned period, except for EVA, where the applicable crew checklists apply.

Testing of the TV system was required in accordance with ED-2002-1269, Rev B, Skylab TV Test Plan and Test Requirements, and was to be performed on a module basis at contractor facilities and in several combined module configurations at KSC. The CSM/MDA/AM configuration test performance criteria with STDN was as follows:

PARAMETER	CRITERIA
Frequency Response	DC to 2 MHz, down not more than X dB, referenced to 0.5 MHz.

	X dB REAL-TIME	X dB DELAYED-TIME
ATM-2	6.5	7.2
AM TVIS	4.3	5.0

PARAMETER	CRITERIA
Transmitter Deviation	3.2 $\pm$0.32 MHz peak-to-peak
DC Response	Tilt $\geq$ 2% (real-time), $\geq$ 7% (delayed time)
K-Factor	Qualitative
Linearity	$\pm$4% (real-time), $\pm$6% (delayed-time of best straight line)
Differential Gain	Qualitative
Signal-to-Noise	$\geq$ 30 dB at - 80 dBm $\pm$0.5 dB input to STDN receiver
Portable Camera VIT Signals	Qualitative
Portable Camera Video	Qualitative
VTR Video	Qualitative

Parameters with qualitative criteria were evaluated for acceptance by specific MSFC and JSC engineers.

Testing was required at selected STDN sites (MIL, GDS, HAW, BDA, TEX) to assure STDN readiness for Skylab TV system support and to determine optimum methods for aligning the audio splitter for demultiplexing audio from the airborne VTR composite video/audio playback signal. No specific criteria was established and acceptance was based on qualitative evaluation by GSFC, MSFC, and JSC engineers.

Comprehensive premission testing of the TV elements in the STU/STDN was required. Individual equipment groups were tested. Total system tests were then performed with simulated camera signals and with flight cameras.

b. Operation Description. Figure 6-18 is a functional block diagram of the Skylab TV system.

(1) Portable Color Camera. Internal and external color imaging are performed with a portable vidicon camera having an output in accordance with EIA Standard RS170 except for modified video to sync ratio of 100:28 and NTSC color line and field rate. Color is field sequential. The camera subject luminance range is 1 to 1000 foot-lamberts with a brightness range of 100:1 for a single scene, and 1000:1 using full ALC range. ALC controls are provided on the camera suitable for both internal and external imaging. Gamma selection of 1.0 for internal and 0.5 for external viewing is provided. The color camera is hand-held or installed on a universal mount for internal viewing. External viewing is performed by pointing through spacecraft windows, emplacement on the S191 Viewfinder Tracking System, EVA through the airlock, or deployment through either scientific airlock. In the latter application, a TV remote control panel is installed on the experiment T027 extension boom.

Manual and remote control zoom lens assemblies are provided with the camera and have the following adjustment ranges:

Zoom	25 to 150 mm
Aperture	f4 to f44
Focus	4 feet to infinity
Angle of view:	
Horizontal	43 to 7.0 degrees
Vertical	32 to 5.5 degrees

A closeup accessory lens is provided for attachment to the main lenses. A portable monitor having a reduced raster scan is provided for use in pointing and focusing the camera.

(2) ATM Cameras. Five external ATM monochrome vidicon cameras are used for solar and other astronomical imaging in operating ATM experiments. H-alpha 1 and H-alpha 2 cameras employ conventional vidicons with a sensitivity of 0.1 foot-candles for full resolution. The WLC and XUV monitor cameras have low light level vidicons with a sensitivity of 3×10^{-3} foot-candles for full resolution. The XUV

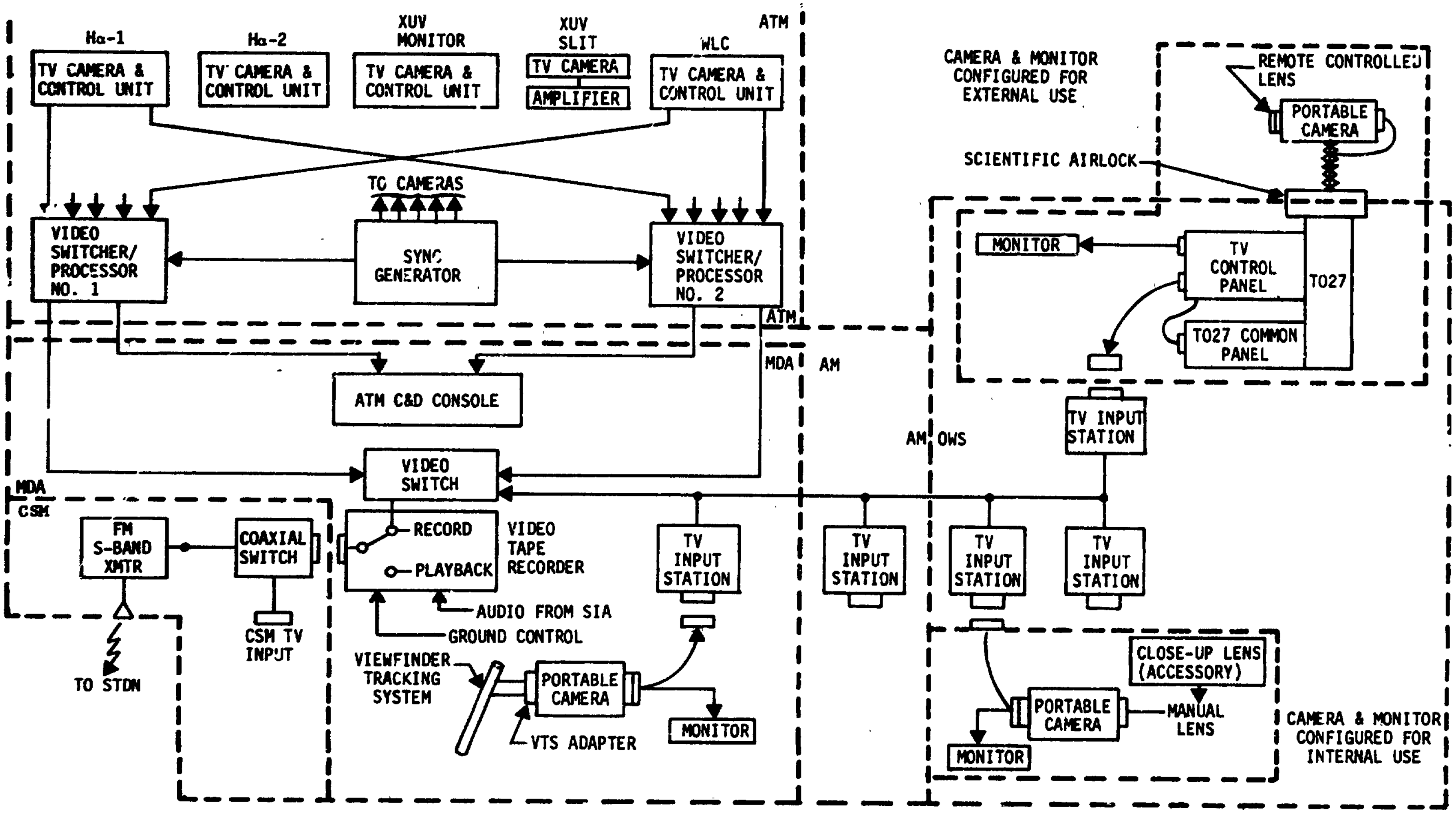


FIGURE 6-18 SKYLAB TELEVISION SYSTEM

slit camera uses an image dissector tube. The ATM composite video signals are in accordance with EIA Standard RS170 except for an aspect ratio of 1:1.

(3) Distribution, Switching, and Signal Conditioning. The portable camera video signal is connected to one of five TVISs, signal conditioned and switched through a single coaxial line to the MDA video switch. This switch also signal-conditions the video signals fed to it on two other redundant coaxial lines from the ATM. Any one of the five ATM video camera signals can be switched by crew remote control of the switcher processors to each of these lines. The switcher processors also insert sync information into the selected ATM video signals. In addition, the selected ATM video signals are routed to the ATM C&D console for display on two TV monitors.

One video signal is manually selected at the MDA video switch from the three input coaxial lines for switching to the MDA VTR and CSM S-band FM transmitter.

Figure 6-19 illustrates the video signal distribution, switching, and signal conditioning within the TV system. RG210 coaxial cable, a low-loss, 93 ohm cable, is used for the video coaxial line from the TVISs up to the MDA video switch. For compatibility with the existing coaxial cabling in the CSM, RG180 coaxial cable is used from the MDA video switch output to the MDA/CSM interface. This results in approximately 65 feet of RG180 cable from the output of the switch to the transmitter input. This length of RG180 represents almost a half wavelength at 4 MHz. The RG180 is smaller in diameter than RG210 and therefore has more loss per unit length and a different velocity of propagation. The difference in velocity of propagation between RG180 and RG210 combined with the half wavelength of RG180 creates a reflection in the line of approximately 10 percent. This reflected signal is dissipated in the output impedance of the TVIS and does not appear at the CSM transmitter input.

Other impedance discontinuities in the line are the internal cabling of the VTR, the video switch and the TVISs and the MDA/CSM interface connector. None of these represent a discontinuity larger than 1 percent of a wavelength at 4 MHz, and therefore have no significant effect. Some of the same kind of impedance discontinuities are present in the ATM video but, again, there is no significant effect.

The video distribution elements are not designed to compensate for roll-off of the high frequencies (2.5 to 4 MHz) in the portable and ATM camera video signals because the CSM transmitter is bandwidth limited at 2 MHz.

The video coaxial line shields are the video signal returns; they were isolated from power and structural grounds throughout the distribution systems. A single point ground of the video return (shield) at the CSM transmitter was utilized. The single point was

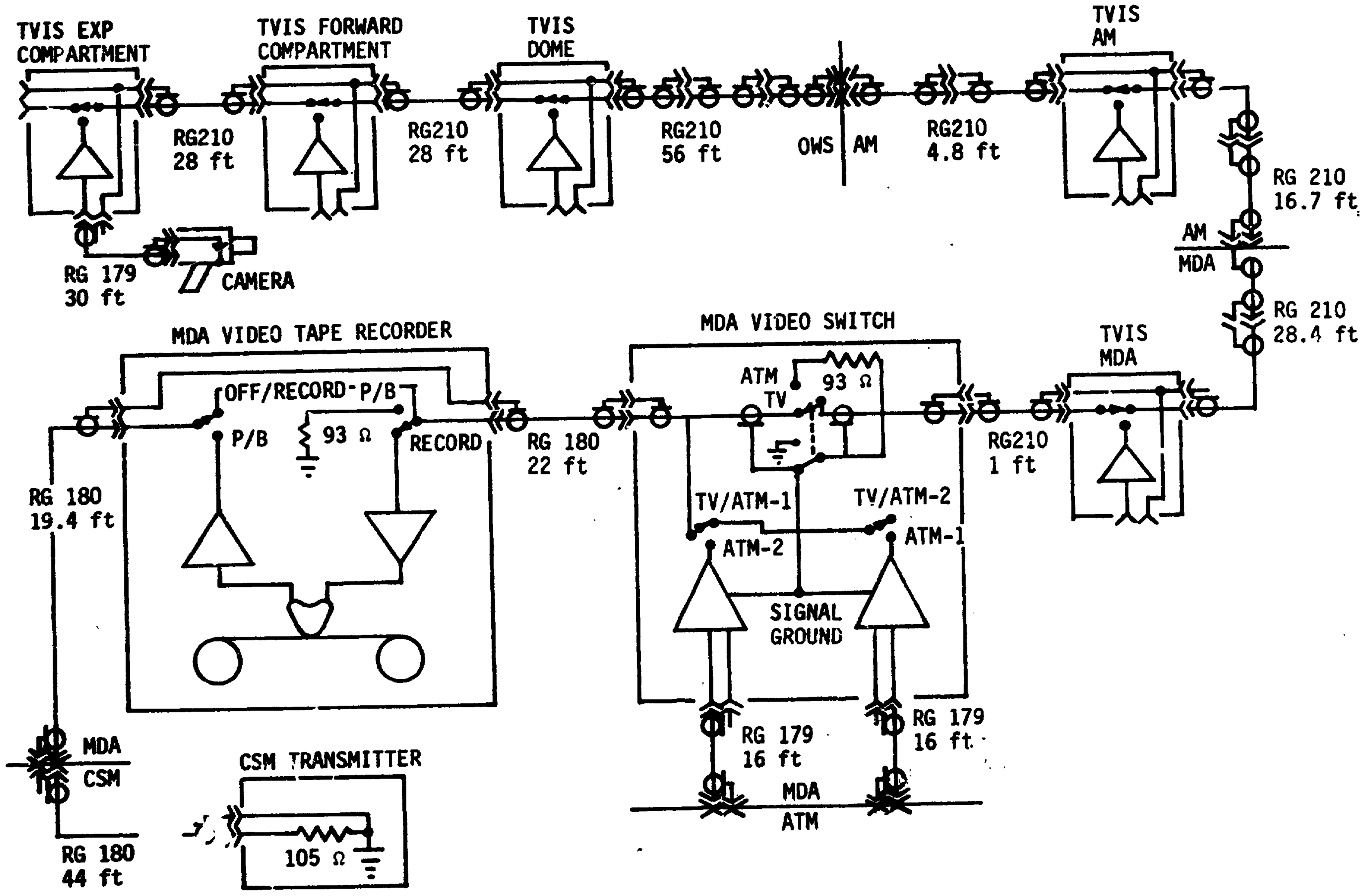


FIGURE 6-19 TV SYSTEM VIDEO DISTRIBUTION

employed to minimize coupling of noise into the video signal through ground loops. The requirement to isolate the video signal return from the spacecraft power return was achieved by the use of DC-DC conversion in the TVIS, MDA video switch, VTR, T027/TV control panel, and in the portable camera. ATM video returns were isolated by isolation amplifiers.

(4) Video Transmission. The VTR, in either the OFF or RECORD modes, provided a loop-through of the video input signal to the CSM transmitter. In the PLAYBACK mode, this loop was opened. The playback electronics output was connected to the transmitter and the input line was terminated in a line matching impedance.

Selected ATM or portable camera video was downlinked in real time to the S-band modulator. Horizontal resolution was reduced to about 200 lines by the transmitter 2 MHz bandwidth. The signal being transmitted could also be recorded at the VTR. However, video recording was primarily intended for performance while out of contact with STDN. The VTR had a 30-minute record capability. Voice signals could be multiplexed with the video. Recording control of the VTR could be performed by the crew or from the ground. Recorder playback was performed by ground control and requires the same time as recording. Fast forward and rewind functions were provided with tape speed four times that for recording.

(5) Interior Lighting. Illumination in the MDA and OWS available for TV viewing was provided by 8 and 42 fixed general illumination floodlights, respectively. These were cool white fluorescent fixtures, each having clear and diffused illumination patterns. Each light was provided with a three-position, manual switch to permit selection of OFF, HIGH, and LOW operation. Illumination in the AM was provided by 24 general illumination lights. All lights were incandescent and had frosted plastic lenses. Intensity controls were available. Portable high-intensity photographic lamps were available for supplementary lighting.

(6) STU/STDN. The STU/STDN facility included both airborne and ground TV elements. Flight hardware comprised a TVIS, MDA video switch, VTR, switcher processor, sync generator, ATM vidicon camera and electronics, CSM coaxial switch and CSM unified S-band system. Four of the TVISs were simulated. Interconnecting cabling simulated flight cabling in length and type. Flight-type connectors were used. The ground elements included a STDN unified S-band receiving section, FM demodulator, Krohn-Hite filter, processing amplifier, Ampex 1200 and 660 VTRs and RCA color converter. Although a portable camera was not provided, a camera output signal recording was available for simulation purposes, if needed. Standard TV test equipment such as a wave form monitor, a test pattern generator, and a field sequential color monitor was available.

(7) STDN. STDN sites at MIL, GDS, and TEX were prime acquisition sites for video data. Video data acquired at these sites are relayed directly to JSC in real-time or delayed-time using telephone wide-band facilities. JSC performed color conversion of the portable cameras video. All other STDN sites supporting the Skylab mission have a capability for acquiring video. Figure 6-20 shows the basic configuration of the video section of a STDN site.

The GDS, TEX, and MIL sites have two quadriplex VTRs, each, and were used as shown in the figure. MSFC data evaluation was performed using the recording made before the processor amplifier (VTR 1). Other sites had helical VTRs, only, except for BDA, HAW, and VAN. Each of these also has one quadriplex VTR. FM receiver front-end bandwidth was 9.5 MHz.

c. Historical. The requirements for the Skylab TV system were first documented in October 1968. The requirements at that time were to provide pictures from the shirt-sleeve environment throughout the cluster, provide pictures with 200-line resolution from the ATM XUV experiment, provide real-time transmission only (with ground recording of TV signals and a possible real-time forwarding from selected continental United States stations), and observe minimum cost, weight, and impact on ground systems.

In May 1969, a study was initiated to analyze the feasibility of the use of two drag-in or preinstalled cables. A configuration using a single preinstalled coaxial cable bus through the SWS with amplifier stations for connecting the TV camera was selected. The amplifiers were necessary due to losses in the cable length required to cover the entire SWS.

The requirements for transmitting ATM signals were met by the installation of a switch in the MDA, to select between signals from the portable television camera and either of two ATM signals. The switch includes amplifiers to achieve a proper interface level for the transmission of the ATM signals. The ATM was modified from its baseline closed-circuit TV system design by the addition of equipment to add a synchronization signal to the TV signal and provide electrical isolation to eliminate a ground loop to ATM structure. A power bus isolation requirement was defined, and DC-DC conversion was implemented in the video switch, TVISs and portable cameras (later in the VTR and T027/TV hardware).

In 1971, system evaluation led to a program to provide external TV viewing capability by deployment of the portable color camera through either scientific airlock. Hardware is designed to mechanically adapt the camera to the experiment T027 extension boom, provide remotely controlled camera lens and ALC circuitry, and provide a TV remote control panel for installation on the interior T027 hardware. This design provided viewing of much of the external spacecraft, including the ATM, without the need for EVA.

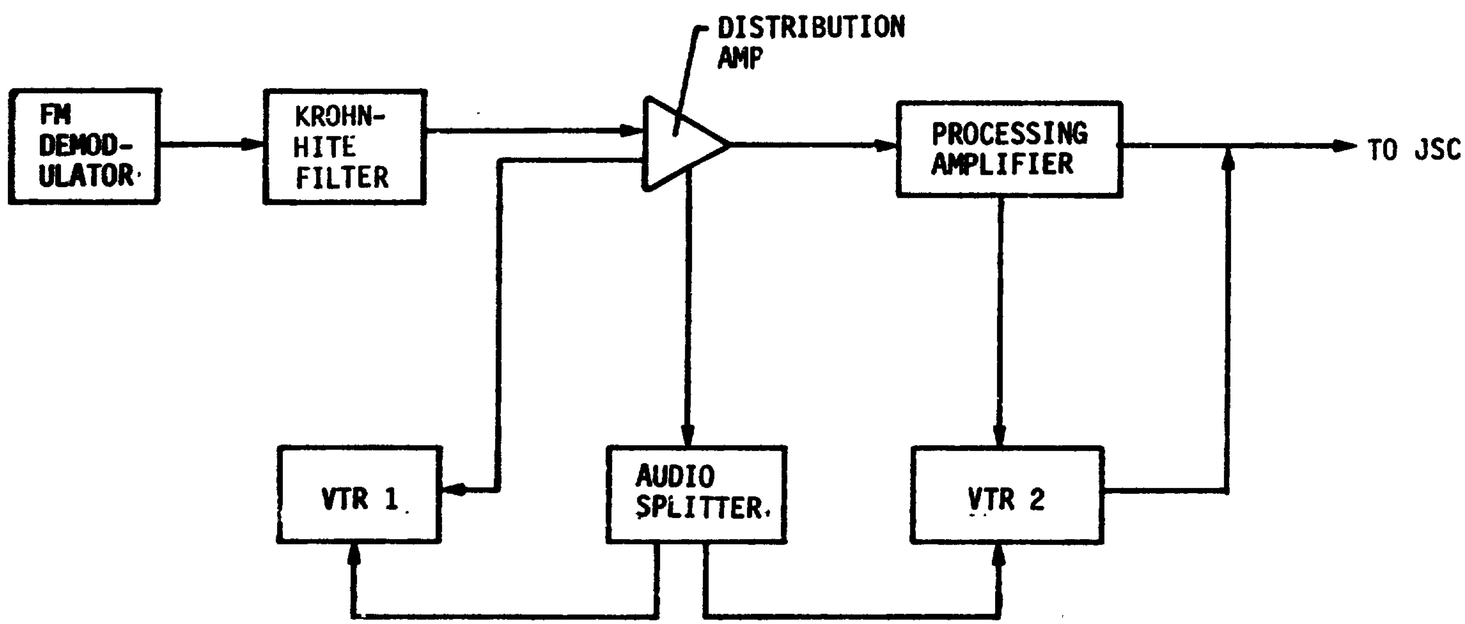


FIGURE 6-20 STDN SITE VIDEO DIAGRAM

During 1971, reviews were made of the feasibility of incorporating a video tape recorder in the Skylab. Late in the year, the decision was made to incorporate a recorder from the Earth Resources Technology Satellite Program modified for incorporation in a manned space vehicle. Manual control was added and provisions made for voice annotation to be multiplexed into the recorded video signals.

During 1972, concern arose that a crew hazard existed should a 28 volt short to the portable camera case occur with the video switch in the ATM position. Figure 6-21 shows the fault path. The problem was resolved by changing the MDA video switch relay contacts to handle the fault current.

2. System Performance

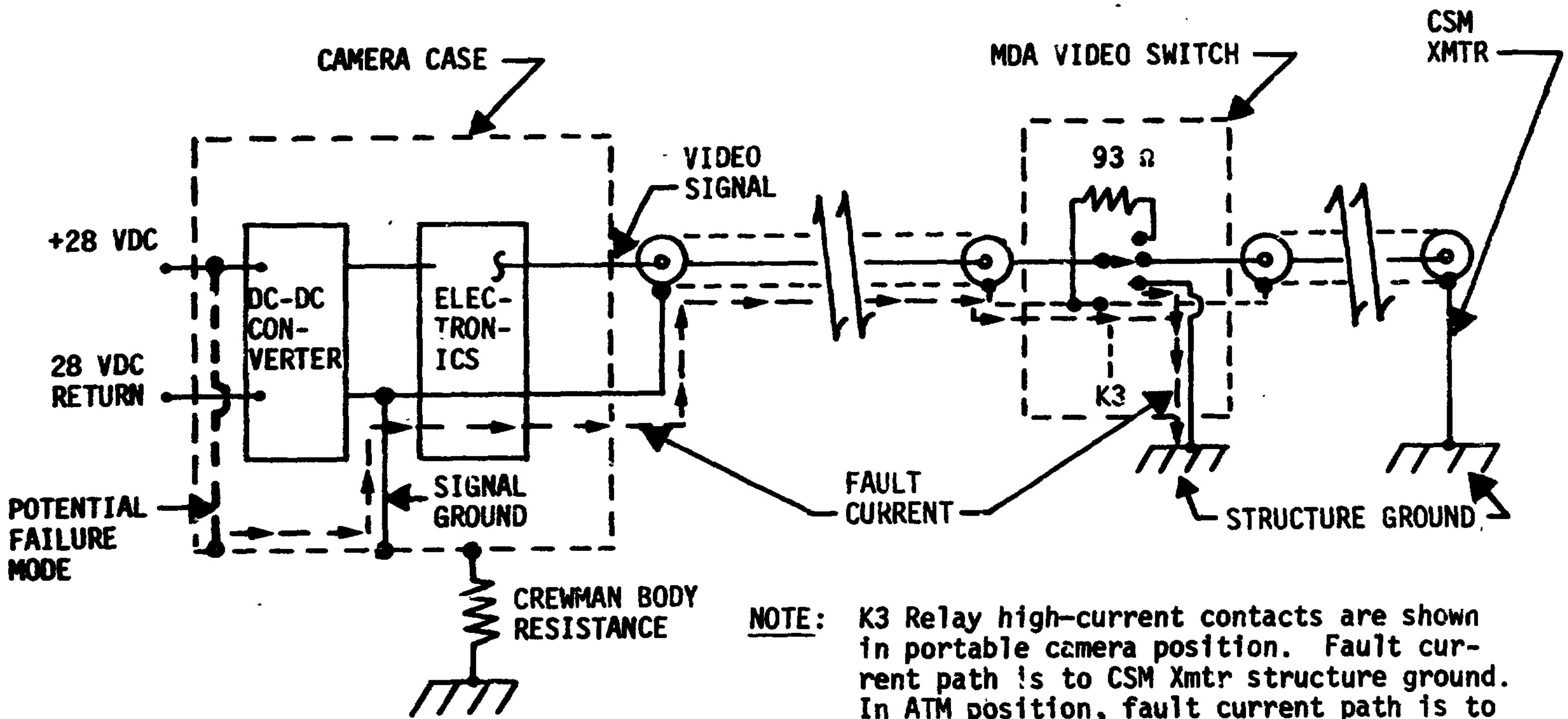
a. Evaluation of Performance.

(1) Evaluation Data Source. TV system performance throughout the mission was evaluated through routine, comprehensive review of video data recorded at MIL. The recordings were made on an Ampex VR 1100 recorder, on low band, at the output of the Krohn-Hite Filter and before the processing amplifier (see Figure 6-20, VTR 1). The processing amplifier removes the original sync information and inserts reconstructed sync. Therefore, a recording made after the processing amplifier would not be suitable for evaluation of the original sync wave form, the portable camera vertical interval test signals and the multiplexed audio signal. The original recordings were sent to MSFC. An unprocessed dub was made at MSFC and sent to STU/STDN for color conversion and further review. In some instances, MIL acquisitions varied in quality from those of the same data at other sites.

(2) Portable Color Camera System

(a) General Discussion. Viewing requirements were satisfied except for external imaging through the scientific airlock. This capability was lost when the solar scientific airlock was permanently allocated to the sunshade and the experiment T027 extension boom failed. System performance discrepancies related to the portable color camera system elements are discussed in subsequent paragraphs on qualitative and quantitative performance. System anomalies were as follows and are discussed in detail in Section VII.

ANOMALY	DOY OCCURRENCE	SECTION REFERENCE
Camera, S/N 3005, Output Failure	153	153
Camera, S/N 3002, Output Failure During EVA	236	236-2
VTR, S/N 4, Output Failure During Playback	214	214
TVIS, Experiment Compartment, Failure Due to Broken Input Connector Pin	362	362



<u>NOTE</u>: K3 Relay high-current contacts are shown in portable camera position. Fault current path is to CSM Xmtr structure ground. In ATM position, fault current path is to structure ground as shown.

FIGURE 6-21 PORTABLE TV CAMERA 28 VDC FAULT CURRENT PATH

ANOMALY	DOY OCCURRENCE	SECTION REFERENCE
Camera Video Image Spots	Throughout Mission	030
Camera/VTS Image Softness	Throughout Mission	031
Camera Power Cable, S/N 3002, Wire Failure	256	256-2
Camera Monitor Cable, S/N 3005, Wire Failure	256	256-2

System performance impact of these anomalies was minimal The failed VTR and TVIS were replaced with inflight maintenance spares. TV scenarios requiring two cameras were constrained until a replacement camera was furnished for the subsequent manned period. The crewmen reported that the mini-monitor was inadequate in size and scene coverage to facilitate and ensure desired scene composition. Concern was also expressed that no efficient means existed to correlate subject distance with focal length and aperture to ensure the desired depth-of-field. They further stated that wider angle lens capability would have been useful. It should be noted at this point that the TV Operations Book established all of the necessary settings to ensure that the content of any scheduled TV scene would be satisfactory. Despite crewmen comments on implementation difficulties, data review indicated that the objective was generally met. Scenes were well composed, angle-of-view was adequate and depth-of-field (including the accessory closeup lens was satisfactory.

The crewmen reported that the Skylab Universal Mount was difficult to use with the TV camera and planned locations. In many cases, they said, improvisation on location was needed. The crew stated that the camera was generally satisfactory for use on EVA. It was suggested that a cable caddy might have been useful to retain the unneeded length of cable.

The crew commented that camera ALC might be improved to better respond to wide variations in scene brightness. The camera was operated in the ALC average and gamma linear modes for internal viewing. This was usually successful, using the preplanned spacecraft lighting configuration for the scene. In some MDA scenes where lighting was quite low, camera gamma in the one-half mode might have yielded better contrast and resolution. Also, where unavoidable bright lighting occurred, such as during activation, operating the camera in the ALC peak mode might have controlled or eliminated the blooming experienced.

On DOY 209, camera S/N 3006 was powered up in the CSM for viewing rendezvous. The color filter wheel failed to run resulting in loss of color but a satisfactory monochrome image that was partially obscured by the stationary wheel. Several days later, the crew removed the lens and manually turned the wheel until normal rotation started. The camera performed nominally for the remainder of the mission.

During activation on DOY 320, video was recorded on the VTR before the CSM/MDA umbilical was connected. This meant the normal CSM transmitter impedance was not on the line. As predicted and verified in testing at STU/STDN before launch, this abnormal system configuration produced an anomalous video signal. Considerable peak white saturation occurred, but some usable video was retrieved.

Location of the TVISs proved satisfactory. The crew commented that an additional station in the MDA for use during EREP equipment viewing would have been useful. Power switch operation and camera cable connection was satisfactory. Replacement of the failed station was routine and no gain readjustment was needed. Video data from this station, after replacement, showed no relatable variation. The MDA video selector switch operated nominally except for one occasion when the switch knob came off. The knob was replaced routinely and did not come off again.

The VTR proved essential in the management of the video data. Most television activity was recorded with the VTR being managed by the crew. When the tape was full, the VTR was dumped by ground control while the crew slept or engaged in other activities. VTR controls and displays functioned normally and were reported as adequate by the crew. VTR, S/N 5, replaced failed S/N 4 during the mission. The installation went smoothly. No performance differences could be noted between the two units, except that S/N 5 had more tape dropouts. This had been known before launch and the dropout per frame occurrence (less than 3 percent) was well within acceptance standards.

The Skylab temperature environment prior to the first manned period was monitored to assess potential impact on the TV system including stowed spares. Components located in the MDA experienced temperatures somewhat below nominal but well above lower limit, and hence, there was no concern for these elements. Investigation of the thermal environment of the docking ring area, where the electrical umbilical carrying the TV signal from the MDA to the CSM is located, was performed. Analysis showed this area peaked at 189° F, whereas the connector, J2, was qualified above 250° F. Concern was expressed for the TVIS (555) in the forward OWS compartment. The actual temperature experienced by the TVIS was not known but the consensus of analyses showed it to be in the 175° to 185° F range. The upper stowage limit for the TVIS was 180° F. The TVIS subsequently performed nominally throughout the entire mission. The spare VTR transport was located in a locker in the OWS dome ring and the Electronics Unit was stowed on the experiment compartment floor. Neither of these units experienced temperatures above their nonoperating limit.

(b) Qualitative Discussion. During the manned mission periods, 121 portable color camera video scenes were evaluated from the MIL data. The important image quality parameters of noise, contrast, spots and blemishes, smear and resolution/depty-of-field were graded on a scale of 1 (poor) through 4 (excellent). A detailed summary of the grading is shown in Appendix E and is intended to convey the extent to which the system provided the required visual data, independent of quantitative considerations. An excellent scene would be one such as the live news conference on DOY 2. This scene was intended for dissemination to a large public audience and was to be visually pleasing. It achieved this objective. Lighting was good and there was a full range of gray scales from the clean, unbloomed white of the wardroom table through the deep black shadows behind the crewmen. This good contrast, together with correct camera location, focal length, focus and aperture settings, resulted in good resolution and depth-of-field. RF and coherent noise were low; spots and blemishes were absent. There was no discernible smearing. Significant sources of noise in the video image were RF noise, airborne VTR tape dropout noise, ground VTR head switching noise transients and noncoherent noise in the camera output. The magnitude of RF noise was directly related to site RF contact parameters. Tape dropout noise was not objectionable and remained at about the same magnitude throughout the mission. Head switching transients were caused by misadjustment of ground VTR during original dub recording and occurred infrequently. Camera S/Ns 3002 and 3006 had been observed in prelaunch testing to have localized light areas in the raster containing noncoherent noise. This condition was not always apparent and seemed to require specific conditions of scene content and lighting. No streaking transients due to audio over modulation were observed. Grading was based on that part of the scene when noise was minimum. The average noise grade was 2.47 with 13 of the 121 scenes (11 percent) being graded as poor.

Evaluation of scene contrast was based on whether sufficient gray shades were contained in the image to convey the intended information. Subject lighting and reflectance, together with coarse grain and flat channel noise magnitude, also influenced the subjective evaluation of this parameter. The average contrast grade was 2.6 with 11 of the 121 scenes (9 percent) being graded as poor.

Camera, S/N 3002, was the only camera having readily observable blemishes. These were in the target; had been noted prior to launch, and were not objectionable. In fact, they served to identify the data from this camera. Grading on this parameter, however, was based primarily on spots observed due to internal camera contamination and external lens/optical contaminations. Of the 121 scenes graded, the average grade for this parameter was 2.7. There were 21 scenes (17 percent) that were considered as poor.

Smear or geometric distortion is a function of frequency response and phasing. It remained acceptable throughout the mission and variations in its grading were largely attributable to the impact of noise and contrast definition on this parameter. The average grade for this parameter in the 121 scenes reviewed was 3.0. There were no scenes in which the parameter was given a poor grade.

Resolution and depth-of-field grading was based on the adequacy of selective focus for the aperture and focal length used. Noise and contrast influenced the evaluation of the 121 scenes reviewed. The average grade for this parameter was 2.6. There were five scenes (4 percent) that were graded as poor.

(c) Quantitative Discussion. Where possible, quantitative performance was measured and compared against the system performance criteria.

The video to sync ratio was required to be 100:28. This parameter was monitored throughout the mission by adjusting the sync amplitude for 40 IEEEU (Institute of Electrical and Electronic Engineers Unit) at the wave form monitor, and measuring the actual amplitude of the internally generated camera vertical interval test signals. The window vertical interval test signal was preset in the camera for a video to sync ratio of 100:40 and provided a convenient means for monitoring this ratio. Appendix F is a summary of these measurements. Variations in the window amplitude beyond plus or minus ten IEEEU were noted and could be attributed to the wave form monitor inaccuracy (plus or minus five IEEEU). Variation in the camera generated window vertical interval test signal amplitude (plus or minus five IEEEU), and compression or amplification of sync within the on-board and/or ground systems. Investigative testing performed during the mission at STU/STDN revealed that drift in DC bias to the transmitter would not cause sync compression. The potential sources of sync compression were the VTR modulator, transmitter modulator, and ground station receiving, demodulating, and recording equipment. The amount of sync compression was computed and entered in the table for the window amplitude adjusted to 100 IEEEU. In two instances, on DOY 149 and 150, measurements reflecting a sync amplification were obtained. A careful, comprehensive test of airborne and ground systems would be needed to isolate the cause of this discrepancy. It is pointed out that at no time did sync begin to approach the 12-to-15 IEEEU levels that would result in loss of recorder and processor amplifier lockup.

The system performance criteria for delayed-time and real-time video signal-to-noise was $\geq$ 30 dB at minus 80 dBm plus or minus 0.5 dB input to the STDN receiver. Throughout the mission, the signal-to-noise ratio varied from 29.5 to 44.5 dB with a norm of about 34 dB being experienced. The signal-to-noise ratio was measured during the cleanest portion of each dump as the ratio of the peak highlight brightness (window amplitude in IEEU) to the value of the noise (peak-to-peak amplitude on IEEEU divided by 6), expressed in dB. The significant noise, when objectionable, was coarse grain, flat channel noise relatable to RF signal strength during the STDN site acquisition.

No relationship could be established between variations in signal-to-noise ratio measured and system configuration at time of measurement.

Throughout the mission, variation in frequency response was monitored by measuring camera multiburst vertical interval test signal amplitude during each dump. The multiburst contained frequencies of 0.525, 1.25, and 2.1 MHz. The amplitude of these frequencies was measured on the wave form monitor in IEEEU with the IEEEU filter switched out. Signal noise and readout accuracy contributed to a measurement error of about plus or minus 1 dB. The following tabulation shows the specification roll-off in frequency response at 2 MHZ, referenced to 0.5 MHz, contributed by individual system elements and by the total system. The average frequency response measured for real-time and delayed-time is given. Little variation in response, within the rather crude accuracy of this measurement, was observed throughout the mission and the values shown here are felt to be representative. The average measured roll-off at 1.25 MHz was minus 2.1 dB and minus 2.6 dB for real-time and delayed-time dumps, respectively.

	SPECIFICATION VALUES						SYSTEM MEASURED VALUE (dB)
	AM TVIS (dB)	VTR (dB)	CSM (dB)	STDN (dB)	VIT (dB)	SYSTEM VALUE (dB)	
REAL TIME	-1.25	-	-3.0	-0.5	-0.5	-5.25	-5.35
DELAYED TIME	-1.25	-0.75	-3.0	-0.5	-0.5	-6.0	-6.0

System DC response variation was monitored throughout the mission by measuring tilt in the window vertical interval test signal generated by the camera. Prelaunch system test criteria required that delayed-time tilt be $\leq$7 percent plus STDN induced tilt. Measurements indicated that tilt remained constant at about 5 to 7 percent.

System K-factor performance was not assigned a quantitative specification prior to launch. Generally, when monitored using the $\sin^2$ pulse, it was less than 4 percent with acceptable absence of ringing. During the mission, K-factor was consistent and greater than 4 percent due to CSM transmitter frequency response roll-off after 2 MHz.

There was no accurate means for measuring system linearity during the mission. The camera-generated stairstep vertical interval test signal was modulated with 1.25 MHz to enable determination of differential gain. Estimations taken from this signal during each dump indicated that linearity and differential gain was acceptable and remained consistent throughout the mission.

Internal camera temperature was monitored throughout the mission, being observed as a vertical interval test signal. The temperature norms and extremes as measured for each camera used are shown below. Camera operational temperature redline was 130° F.

CAMERA S/N	NORMAL °F	MAXIMUM °F	MINIMUM °F
3002*	87	160*	80
3004	93	107	80
3005	95	113	72
3006	81	107	77

*This camera failed on DOY 236 during EVA due to overheating.

(3) ATM System. ATM TV system performance was monitored qualitatively throughout the mission. With the exception of the XUV MON camera test pattern video, it was not possible to make quantitative assessments since there were no internally generated signal parameters available for this purpose. Further, normal image content did not lend itself to a comprehensive qualitative analysis of such parameters as contrast, resolution, depth-of-field, geometric distortion, etc. The XUV Slit (image disector) camera signal was not downlinked regularly and was not evaluated. Video signals from the H-alpha 1, H-alpha 2, WLC, and XUV cameras, as evaluated on the wave form monitor, remained consistent in wave form and amplitude characteristics. A specific review of WLC camera signal characteristics was conducted using data acquired during each of the manned periods. No significant variations were noted.

The following anomalies occurred within the ATM TV elements:

ANOMALY	DOY OCCURRENCE	ANOMALY REPORT NO.
WLC Vidicon Burns	341 and 28	341
TV Monitor 1 Failure	260	260
H-alpha 1 Image Degradation	18	18

None of the above imposed serious limitations on the ATM TV system performance. The WLC camera burns occurred late in the mission and occupied only a small portion of the raster. The monitor failure occurred several days before the end of the second manned period and was largely offset by use of the second monitor. It was replaced at the start of the third manned period. H-alpha 1 image degradation occurred near the end of the mission and was somewhat offset by the operational work-around of turning the camera off when not in use.

Several instances of oscillatory blooming in the H-alpha 2 camera image occurred during the mission. This was caused by ALC circuit response to sudden high light levels when the camera was turned on. This condition could be prevented by setting the telescope to the X5 zoom position before turn-on, to reduce light intensity at the vidicon target. On DOY 264, it was observed that the H-alpha 2 camera was accumulating residual image. This was caused by lengthy periods of imaging the black telescope mask with transition to the bright solar image. This response is inherent to a vidicon target, and it was recommended that the telescope be left in X5 zoom position when not in use to provide uniform light intensity across the vidicon target.

The XUV MON camera was powered continuously throughout the mission to implement experiment thermal control. This continuous use was unplanned and caused concern that some image deterioration would result. Therefore, the internal test pattern was monitored periodically throughout the mission to observe for onset of any deterioration in camera performance. No deterioration was observed. The crew commented that a high persistence screen in the monitor would have been helpful in monitoring the integrated image from this camera.

On DOY 259, the crew said that TV monitor 1 was slow in achieving operating brightness and was noisy. The TV downlink was nominal. This condition did not occur again and on DOY 260 the image was described by the crew as normal. The crew stated that TV monitor 1 was consistently the better monitor and that monitor 2 took on a yellow cast during the mission. They were unable to discern any change in the relative image quality between the two monitors.

Subsequent operation of TV elements after the short experienced on TV bus 2 showed them to be nominal and undamaged. Telemetry measurements of the current showed no rise during the short. A subsequent measurement of the bus impedance while replacing TV monitor 1 showed no short existing at that time.

(4) Video Sync. The video signal sync wave form as evaluated from the unprocessed signal was satisfactory. Some tilt was consistently present due to the Krohn-Hite filter effect introduced at the STDN sites.

Several STDN sites conducted measurements of long-term vertical sync jitter and reported up to 12 μ seconds peak-to-peak excursions in the received signal. Such excursions would be excessive and a sync stability measurement effort was undertaken at MSFC. ATM and portable color camera horizontal sync jitter and portable color camera real-time and delayed-time VTR vertical sync jitter measurements were made. Measurement data are shown in Table VI-7.

The average horizontal frequency during a 10-second period was measured with an HP5245 counter and compared with the standard frequency of 15750 Hz. The formula used to calculate Δt is:

$$\frac{1}{15750} - \frac{1}{f} = \Delta t \qquad f = \text{measured horizontal frequency.}$$

Table VI-7. Video Sync Jitter Measurement Summary

HORIZONTAL SYNC	
ATM	
f(Hz)	Δt(nsec)
15752.4	9.67
15753.5	14.11
15752.6	10.48
15752.0	8.06
15752.3	9.27
15751.3	5.24
15751.4	5.64
15751.0	4.03
15750.4	1.61
15750.5	2.02
15751.4	5.64
15750.3	1.21
15750.5	2.02
15751.9	7.66
15752.8	11.29
15753.9	15.72
15752.7	10.88
15752.7	10.88
15752.1	8.46
15752.4	9.67
15752.6	1.05
15752.0	8.06
15752.6	1.05
15752.4	9.67
15753.2	12.90
15752.6	10.48
15751.9	7.66
15750.3	1.21
15749.5	- 2.02
15750.0	0
15750.4	1.61
15750.6	2.42
15749.4	- 2.42
15747.8	- 8.87
15746.9	- 1.25
15747.2	-11.29
15748.5	- 6.05
15749.4	- 2.42
15748.4	- 6.45
15749.1	- 3.63
15750.2	8.06
15750.0	0

HORIZONTAL SYNC		PORTABLE COLOR CAMERA/VERTICAL SYNC											
PORTABLE COLOR CAMERA		REAL TIME						DELAYED TIME					
		2 sec AVERAGE		5 sec AVERAGE		10 sec AVERAGE		2 sec AVERAGE		5 sec AVERAGE		10 sec AVERAGE	
f(Hz)	Δt(nsec)	τ(msec)	Δt(μsec)	τ(msec)	Δt(μsec)	τ(msec)	Δt(μsec)	τ(msec)	Δt(μsec)	τ(msec)	Δt(μsec)	τ(msec)	Δt(μsec)
15752.5	10.08	16.66454	1.29	16.66644	0.40	16.66673	0.90	16.66639	1.01	16.66650	3.55	16.67073	0.81
15751.5	5.64	16.66469	1.14	16.66554	1.29	16.66779	-0.16	16.66641	0.99	16.67105	-0.98	16.67187	-0.33
15751.7	6.85	16.66588	- .05	16.66643	0.40	16.66824	-0.61	16.66695	0.45	16.66776	2.29	16.67173	-0.19
15752.1	8.46	16.66590	- .06	16.66661	0.22	16.66814	-0.51	16.66639	1.01	16.66846	1.59	16.67287	-1.33
15752.5	10.08	16.66685	-1.02	16.66583	1.00	16.66735	0.10	16.66668	0.72	16.66955	0.50	16.67158	-0.04
15752.1	8.46	16.66690	-1.06	16.66429	2.54	16.66754	0.09	16.66716	0.24	16.67004	0.01	16.67081	0.73
15752.5	10.08	16.66646	-0.63	16.66493	1.90	16.66839	0.76	16.66700	0.40	16.67026	-0.21	16.67012	1.42
15752.3	9.27	16.66529	0.54	16.66590	0.93	16.66812	0.49	16.66709	0.31	16.67122	-1.17	16.67117	0.37
15751.6	6.45	16.66434	1.49	16.66600	0.83	16.66784	-0.21	16.66826	-0.86	16.67090	-0.85	16.67236	-0.82
15751.4	5.64	16.66448	1.35	16.66678	0.05	16.66000	-1.63	16.66796	-0.56	16.67166	-1.61	16.67209	-0.55
15750.4	1.61	16.66479	1.04	16.66652	0.31			16.66775	-0.35	16.67211	-2.06	16.67158	-0.04
15751.3	5.24	16.66475	1.08	16.66642	0.41			16.66786	-0.46	16.67204	-1.99		
15751.1	4.43	16.66637	-0.54	16.68121	-4.38			16.66751	-0.11	16.67146	-1.41		
15750.1	2.82	16.66632	-0.49	16.66903	-2.20			16.66749	-0.09	16.67082	-0.77		
15750.2	0.81	16.66651	-0.68	16.66685	-1.72			16.66815	-0.75	16.66929	0.76		
15750.5	2.02	16.66693	-1.10	16.66751	-0.68			16.66801	-3.61	16.66896	1.09		
15751.5	6.05	16.66711	-1.28	16.66751	-0.68			16.66856	-1.16	16.66906	0.99		
		16.66697	-1.14	16.66724	-0.41			16.66855	-1.15	16.66968	0.37		
		16.66589	-0.06	16.66723	-0.40			16.66757	-0.17	16.66990	0.15		
		16.66571	-0.12	16.66672	0.11			16.66712	0.28	16.66949	0.56		
		16.66598	-0.15	16.66669	0.14			16.66725	0.15	16.66996	0.09		
		16.66563	0.20	16.66691	-0.08			16.66680	0.60	16.67059	-0.54		
								16.66731	0.09	16.67045	-0.40		
		τ AVG = 16.66583 msec		τ AVG = 16.66683 msec		τ AVG = 16.66763 msec		τ AVG = 16.66740 msec		τ AVG = 16.67005 msec		τ AVG = 16.67154 msec	
		f AVG = 60.00301 Hz		f AVG = 59.99940 Hz		f AVG = 59.99653 Hz		f AVG = 59.97358 Hz		f AVG = 59.98782 Hz		f AVG = 59.98247 Hz	

The jitter was less than 10.08 nonoseconds. This is well within the lock capability of color converters and video tape recorders.

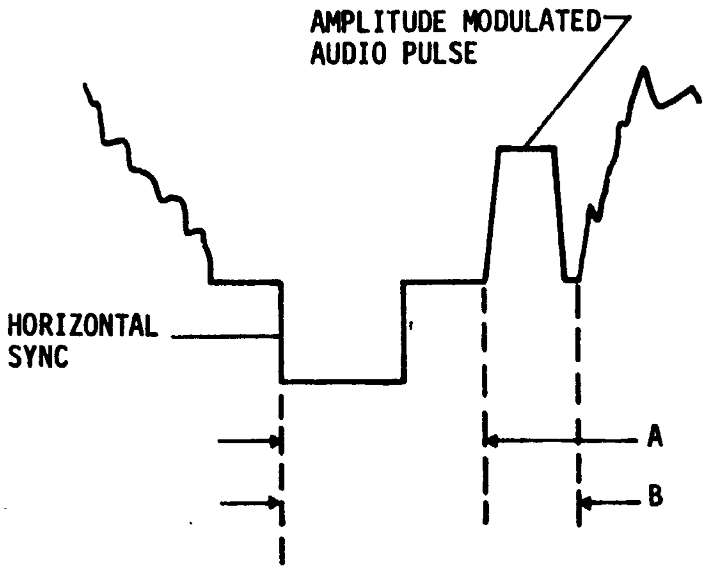
In order to achieve an accurate measurement of the low vertical sync frequency of 60 Hz, all measurements were made in terms of the period measurement (t) rather than frequency. No significant differences between real-time and delayed-time were noted. Three different averaging times were used in obtaining the raw data points: 2 seconds, 5 seconds, and 10 seconds. This extended the measurements from short-term stability to long-term stability. The Δt is calculated from the average period of the measurements. Unexpectedly, the 5-second averaging time yielded the highest Δt, both for real-time and delayed-time. The Δt for delayed time showed excursions from plus 3.55 to minus 2.06 μ second. For real-time transmission, the excursion was plus 2.54 to minus 4.38 μ second. In both cases the peak-to-peak excursion was in the range of 6 μ second. It would not affect the ability to record a downlinked signal on a video tape recorder such as the Ampex 1100 or RCA TR5. However, it could be enough to disrupt a color converter. There was one instance of this reported. Processing before color conversion usually included a retiming of sync and removal of most of this jitter. It was felt that most of this jitter was initiated in the STDNs VR 1100 tape recording with only a small contribution from the onboard TV system. There was no suitable means at STDN or at MSFC to measure jitter of the downlink video sync prior to recording.

(5) Audio. VTR audio intelligibility was satisfactory whenever the communications carrier or lightweight headset was worn properly. It was found that when hand-held, great care was necessary to properly locate the microphone at the lips with respect to orientation and distance. Otherwise, intelligibility varied from acceptable to unusable. A hand-held microphone produced degraded data in operating into the VTR. During voice annotations, modulation of the PAM pulse was generally over the full range. No significant overdriving occurred and no degradation of the video signal due to audio-induced streaking was noted.

Measurements were made during the mission of the time location of the audio pulse within the video signal of each VTR. Figure 6-22 shows the wave form and the location specification for the pulse. Measurements are tabulated and it can be seen that pulse location and width is slightly out of specification. This condition remained stable and no evidence of audio or video degradation could be attributed to it.

(6) S-band FM Video Downlink. Received S-band FM video downlink signal strength was adequate during orbits and at STDN sites where usable contacts had been predicted. In many cases, good data were obtained at MIL during unscheduled passes. High RF noise content, when experienced during video passes, could be related to low elevations and predicted obscurations.

WAVEFORM



SPECIFICATION

A = 9.0 to 9.2 Microseconds
B = 10.6 to 11.0 Microseconds

MEASUREMENTS

DAY (1973)	DUMP NO.	CAMERA S/N	VTR S/N	MICROSECONDS			
				A		B	
				MSFC	STU	MSFC	STU
46	PRELAUNCH TEST KS0045	3002	004	--	9.40	--	11.40
47	PRELAUNCH TEST KS0045	ATM	004	--	9.40	--	11.40
153	16-1	ATM	004	9.32	9.70	11.71	11.90
153	17-3	3002	004	9.22	9.53	11.61	11.75
159	32-1	ATM	004	9.55	9.53	11.75	11.75
159	33-3	3002	004	9.55	9.40	11.77	11.60
260	188-2	3006	005	9.70	--	11.90	--

FIGURE 6-22 PULSE AMPLITUDE MODULATION TIMING MEASUREMENTS

Table VI-8 shows received signal strength, both calculated and measured, for selected orbits at GDS and MIL. The lower signal strengths at MIL were due to the use of a 30-foot dish antenna instead of an 85-foot dish as used at GDS. Full-scale recorder range at both sites was minus 68 dBm which resulted in off-scale indications at GDS, as shown. Calculated values are premission worst-case values; and it can be seen that in almost all cases, the measured values are above the calculated values. Up to 3 dB of the difference is accountable to CSM antenna gain variables, such as orientation with respect to the receiving antennas. The exact transmitter power is also a variable as a nominal specification value of 12.5 watts was used in the calculation.

During premission signal-to-noise testing at MIL, a signal strength of minus 80 dBm, minimum, was required to ensure a video signal undegraded by the RF link. This is a conservative level, but even so it was exceeded in most cases by the measured values during the mission. In the MIL acquisition on DOY 151 (dump 184-1), the video had high RF noise content which is explained by the minus 86 to minus 90 dBm signal strength measured. However, best signal-to-noise during this pass reached 32.7 dB and an acceptable image was obtained.

Nominal RF deviation for the video downlink was specified at 3.2 plus or minus 0.32 MHz, and STDN operational configuration was based on this value. Distribution amplifiers feeding tape recorders and processing amplifiers were set up for a video/sync ratio of 100:28 or 100:40 at a peak voltage of 1.68 from the FM demodulator. On DOY 210, GSFC reported that the sites were experiencing decreased deviation (about 11 percent) and that adjustments were being implemented to achieve the above ratios with a peak voltage of 1.5 from the FM demodulator. If change in deviation had actually occurred, the amount of adjustment required reflected a new deviation nominal of 3.0 MHz, still within the specification. The only onboard system element that could account for a common decreased deviation value for all video downlink signal sources would be the new CSM. It is significant to note, as described previously, that from this time on, a definite increase in the amount of apparent sync compression occurred.

(7) STU/STDN. The mission video data evaluation conducted at STU/STDN was coordinated with that carried on at MSFC to provide ongoing assurance of satisfactory system performance and to detect any anomalous conditions. The VR1100 dubs provided to STU/STDN after the first manned periods, in lieu of the VR660 original recordings, provided data for evaluation that were less noisy and generally produced much improved NTSC color conversion.

The color converter was set up using standard color bar signals that had been prerecorded by MIL at the beginning and end of each scene. This gave the conversion system a standard setup with no compensation for the camera color wheel filters or the nonstandard

Table VI-8. Received Signal Strength, S-Band FM Link

STDN STATION	D55660 STRIP CHART NO.	SKYLAB ORBIT NO.	TIME GMT	RANGE n mi	ANTENNA ELEVATION DEGREES	RECEIVED RF SIGNAL LEVEL IN dBm	
						MEASURED	CALCULATED
MERRITT ISLAND	730917	1823	--	362	-	-80	-80.6
	730916	1809**	2226	625	-	-90	-85.3
	730916	1809**	2227	775	-	-86	-87.2
	730916	1810	2359	800	-	-82.5	-87.5
	730916	1810	0001	550	-	-80.0	-84.2
	730916	1810	0001.4	540	-	-80.0	-84.1
GOLDSTONE	730919	1848	1647.6	231.8	82.6	-68 *	-68.7
	730919	1849	1825.2	692	14.2	-68 *	-78.2
	730919	1850	2003.9	945	6.7	-74	-80.9
	730919	1851	2142.2	789.5	11.0	-71	-79.4
	730919	1852	2320.2	312.7	46.4	-68 *	-71.3
GOLDSTONE	730920	1862	1603.8	266	58.6	-68 *	-69.9
	730920	1863	1741.4	597	18.2	-68 *	-76.9
	730920	1864	1919.9	925	7.2	-72.5	-80.8
	730920	1865	2058.2	854	9.1	-72.5	-80.1
	730920	1866	2236.4	417	31.0	-68 *	-73.8
	730920	1867	0013.4	481	25.0	-68 *	-75.2
GOLDSTONE	730921	1878	1836.1	890	8.1	-72.5	-80.4
	730921	1879	2014.8	910	7.8	-72	-80.6
	730921	1881	2329.8	342.2	40.6	-68 *	-72.1

*RECORDER OFF SCALE
**DUMP 184-1

color temperature of the lighting aboard Skylab. The result was that all scenes had a yellowish to greenish tint, particularly with camera S/N 3005. Scenes taken with camera S/N 3002 did not have as prominent a color shift and at times, flesh tones of the crew were almost a normal sun-tan color. All scenes exhibited a lack of color saturation, but this could be due to lack of colorful scenes to view. The interior of the spacecraft was mainly tones of gray, and the crew flight suits were beige. The colors of the American flag and NASA patches on the flight suits were acceptable but still not as saturated as the actual colors. The color differences from scene to scene and as a crewman moved around are most probably attributable to lighting conditions onboard. This is most apparent in scenes of the AM and EVAs. All of these effects, however, could be compensated for on the ground color conversion and good color quality could be produced from the TV system.

In addition to system performance monitoring, the TV elements in STU/STDN were employed in responding to actual requests for problem investigations throughout the mission.

(8) STDN. The quality of the original VR1100 recordings furnished by MIL during the entire mission was consistently good. The VR1100 recorders at MIL had only low band (5.5 MHz) recording capability.

b. Inflight Maintenance and Repair. The following TV system inflight maintenance spares were carried:

1 - TVIS
1 - VTR (Electronics Unit, transport, interconnecting cables)
1 - Video selector switch
1 - VTR power cable

Second portable cameras, camera cables, lenses and monitors were not considered as spares because some scenarios called for use of two cameras.

When the flight VTR failed, no permanent system impact was experienced as the inflight maintenance unit was installed without problem and performed nominally. Using an uplinked procedure, the crew removed the suspected circuit boards from the failed VTR and packaged them for return. For the following manned period, replacement printed-circuit boards were provided but were not needed. No significant impact was experienced when the TVIS in the experiment compartment failed. The inflight maintenance spare, after installation performed nominally throughout the mission.

Camera and camera cable failures that occurred during the first two manned periods resulted in some video data loss from those several scenarios where use of two cameras had been planned.

Failure of the ATM monitor 1 at the end of the second manned period did not constitute a profound system degradation since the other monitor remained operable. However, that most useful capability of viewing several camera images simultaneously was lost until replacement of the failed monitor at the start of the third manned period.

On DOY 209, during rendezvous, the camera filter wheel failed to run. Several days later, the crew removed the lens and manually started the wheel. The camera operated nominally for the rest of the mission. It was necessary for the crew to clean the camera lenses (externally) throughout the mission, using onboard lens cleaning items.

3. End of Mission Configuration. During the mission, a conflict occurred in the timeline of equipment sharing the MDA high outlet with the VTR. A 60-foot cable was formed with onboard cables to power the VTR from an outlet in the OWS. Analysis had shown that the lowest power voltage to the VTR that could be expected in this configuration would be within the VTR lower input voltage requirement. The VTR performed nominally.

It was not necessary to add operating constraints on the TV system because of configuration changes brought about by equipment failures. As stated above, equipment failures were essentially covered by inflight spare utilization without significant configuration change. Normal significant equipment operation constraints related to use of the cameras in vacuum and to what was essentially good operating practice for the VTR.

SECTION VII ANOMALY REPORTS

The anomaly reports in this section consist of updated and edited versions of the Mission Problem Reports generated during the Skylab mission. The anomaly report numbers represent the DOY the problem first occurred.

ANOMALY REPORT 134

1. Statement of Problem:

   ATM Coaxial Switch Failure.

   The ATM RF link consisting of transmitter 1, coaxial switch 1, RF multicoupler 1, and the aft antenna exhibited high reflected power on DOY 134 at 19:13.

2. Investigative Action:

   The ATM telemetry RF system was operating nominally during the first STDN pass, CRO 134:18:23 to 134:19:29, with transmitter 1 on the aft antenna and transmitter 2 on the forward antenna. Operation was nominal at the next sites, HSK 18:34 to 18:37, and TEX 19:05 to 19:10. At TEX 134:19:05, transmitter 1 was switched to the forward antenna by coaxial switch 1. Operation was nominal throughout the pass, which ended at 134:19:10.

   At TEX 134:19:11, transmitter 1 and transmitter 2 were switched through RF multicoupler 1 to the aft antenna. This switching occurred after LOS telemetry so no data are available.

   At MIL 134:19:13, the RF link consisting of transmitter 1, coaxial switch 1, RF multicoupler 1, and the aft antenna exhibited high reflected power (transmitter 1 reflected power = 8.6 watts, nominal is $<$0.5 watt and specification value $<$2.0 watts). The RF link was in this configuration for 62 minutes.

   Transmitter 1 was turned off at 134:20:12. Transmitter 1 was turned on from 134:20:41 to 134:20:45 and had high reflected power. Transmitter 1 was cycled from aft to forward three times and left in forward position; transmitter 1 was then turned on at 134:22:34 and operation was nominal.

   Transmitter 2 incident and reflected power remained nominal on both forward and aft antenna.

The problem was simulated on the ATM I&C Simulator in the Astrionics Laboratory at MSFC. Since the reflected power was high, the possible location of the fault was limited to points from the input to the coaxial switch to the input of the RF multicoupler. Seventy-five percent of the power was reflected on the flight system. Sixty-five percent of the power was reflected at the coaxial switch on the simulator, and fifty-two percent of the power was reflected at the input of the multicoupler by shorting or opening the cables.

This anomaly eventually led to a mission constraint that transmitter 1 be constrained to the forward antenna; transmitter 2 would continue to be switched between either of the two antennas. It is difficult to quantitatively assess the impact that this constraint had on data recovery. Because of the capability to switch the real and delayed-time PCM data between either transmitter, and the need to dump the ASAP tape recorder only about once per revolution.

The ATM coaxial switch was not accessible for crew repair or replacement.

3. Conclusions:

Since the simulated coaxial switch failure came closer to the actual flight condition it was assumed that the switch was the failure point.

The coaxial switch was in an inaccessible location and its replacement or repair was unfeasible.

The coaxial switch 1, linking transmitter 1 to the forward antenna, allowed satisfactory transmission from transmitter 1 to the ground.

4. Corrective Action:

None to flight hardware.

Ground operations and management procedures required modification to include the restricted switching of transmitter 1 to the forward antenna.

5. Mission Effect:

No impact on the overall mission objectives.

No changes required to the system configuration or hardware.

The ground operation procedures (mission operations and management) required modification to restrict the transmission of the VHF output signal of transmitter 1 through the forward antenna only. A precautionary note was added to the procedures to prevent inadvertent switching of transmitter 1 from the forward antenna.

ANOMALY REPORT 153

1. Statement of Problem:

Portable Color Camera, S/N 3005, failure.

On DOY 153, camera, S/N 3005, lost all output abruptly. The camera had been accidently jarred by the crew during a two-camera scene in the OWS.

2. Investigative Action:

An attempt was made to operate the failed camera from another TVIS without success. The crew verified that the color filter wheel was not jammed. The camera was returned and failure analysis revealed contamination particles in a hybrid microcircuit in the sync generator-VIT signal adder section of the camera.

3. Conclusions:

It was concluded that the contamination particles were large enough to short out the sync output and cause complete video output signal loss.

4. Corrective Action:

None. The problem occurred through manufacturing shortcomings rather than through a design deficiency. There was no practical way to determine if such contamination existed in other cameras.

5. Mission Effect:

Scheduled two-camera television activities had to be revised for single-camera coverage for the remainder of the first manned period.

ANOMALY REPORT 159

1. Statement of Problem:

AM Tape Recorder 1, S/N 13, failure.

On DOY 159 at 07:50 GMT during a pass over BDA, the tape motion monitor was observed to go off. At this time no recorder related commands were sent. Operation prior to this, including the previous dump of this recorder at 06:06 to 06:12 over MIL/BDA had been normal. The recorder had been recording from 06:12 to 07:50, which placed it 1 hour and 38 minutes into the record cycle at the time of failure.

2. Investigative Action:

On DOY 159 at 07:58 GMT, the data and voice enable and execute commands were sent. The tape motion monitor did not respond and the crew observed that the tape recorder stop light on AM Panel 204 was on. Observation of transmitter modulation revealed noise instead of intelligence. Ground site tapes from BDA were sent to the Skylab Test Unit at St. Louis and analyzed with the following conclusions:

Tape recorder was not at end of tape when it stopped;

Tape recorder had power applied;

The proper commands were sent, received, and executed.

On DOY 227 the SL-3 crew disassembled the failed recorder and discovered that the yellow drive belt (designated belt 5) between the tape motor and the speed converter assembly was broken at a 45 deg. angle.

3. Conclusions:

Tape Recorder, S/N 13, in SL-1 recorder 1, failed on DOY 159. The cause of this failure was attributed to a 45 degree break in belt 5 (yellow) between the tape drive motor and the speed converter assembly, as discovered by the SL-3 crew on DOY 227. S/N 13 had exceeded its design life requirements of 750 hours. It had operated 1213 hours before failure.

4. Corrective Action:

On DOY 159 the SL-3 crew installed spare recorder, S/N 22.

5. Mission Effect:

Three hours of recorded data were lost and a replacement recorder was required.

Due to the failure of S/N 13 and an additional failure of S/N 22 on DOY 173, two replacement recorders (S/N 32 and 34) were flown up on SL-3.

On SL-4 a tape recorder repair kit was flown up to replace the broken belt on S/N 13 and 22. This repair kit insured that the recording capability for the mission could be met if additional recorders failed.

See Anomaly Report 173.

ANOMALY REPORT 163

1. Statement of Problem:

Loss of Airlock A10 Transmitter.

On DOY 158 the STDN reported a loss of signal from the "A" 10-watt transmitter. This loss of signal coincided with the spacecraft atmospheric venting process during EVA preparation. The "A" 2-watt transmitter was activated and telemetry data were restored. Approximately 6 hours later the "A" 10-watt transmitter was reactivated and provided real time telemetry transmissions until DOY 163 when failure reoccurred.

2. Investigative Action:

Data were reviewed from the Hawaii pass at 19:14 GMT on DOY 163. Evaluation revealed that the "A" 10-watt transmitter case temperature was significantly cooler than the other operational transmitters, and that the AM bus current indicated no change, or a decrease in current when the 10-watt transmitter was selected in place of the 2-watt unit. In addition, the "A" 10-watt case temperature measurements prior to DOY 163 indicated a higher operating temperature. These facts coupled with the decrease in received signal indicated that the "A" 10-watt transmitter RF output power had degraded significantly.

3. Conclusions:

The A10 transmitter power output had degraded to an unusable level. Analysis of data confirms failure of AM A10 transmitter. The A2 transmitter can support the mission with no degradation in telemetry data. The most probable cause of the loss of the transmitter is a failure of the RF power amplifier section within the transmitter.

4. Corrective Action:

The "A" 2-watt transmitter was used in place of the "A" 10-watt transmitter.

5. Mission Effect:

AM transmitter A10 was lost for the duration of the mission. This resulted in off-nominal transmitter management. The real-time data were downlinked via transmitter B10 instead of transmitter A10 except when two AM tape recorders were dumping simultaneously: then real-time data were downlinked via the A2 transmitter.

ANOMALY REPORT 173

1. Statement of Problem:

AM tape recorder 1, S/N 22, failure.

On DOY 173 over HAW on Rev 563, a tape recorder 1, S/N 22, dump was attempted. The HAW station indicated that transmitter C appeared to have varying modulation rates and STDN could not lock onto the data. During the time the tape was being dumped, the tape motion monitor indicated the tape was moving. At the time of loss of signal at HAW, the tape dump enable and execute commands had been reset and the tape recorder failed to operate as indicated by the motion monitor parameter.

2. Investigative Action:

On DOY 173 at 15:16 GMT, upon AOS at HAW the tape motion monitor was off. The previous dump over VAN at 12:32 to 12:36 GMT had been normal and it returned to record mode after the dump. The last observed tape motion was at 14:18 GMT at VAN LOS. No later data was available until acquisition by HAW at 15:16 GMT. This placed the apparent failure at between 1 hour 42 minutes and 2 hours 40 minutes into the record cycle.

During three subsequent passes, attempts were made to dump the recorder with no success. The tape motion monitor would not respond, the playback mode detect did respond indicating that the recorder had power and was receiving the playback command. During each attempt, modulation was noted on the transmitter. It was determined from STU testing of similar recorders that this type of modulation was possible with the recorder playback electronics powered and no tape movement over the playback head. Each recorder exhibited slightly different output characteristics under this condition.

On DOY 227 the SL-3 crew disassembled the failed recorder and discovered that the yellow drive belt (designated belt 5) between the tape motor and the speed converter assembly was broken. The crew reported it was a 90 degree break.

3. Conclusions:

AM tape recorder 1, S/N 22, failed on DOY 173. The cause of this failure was attributed to a 90 degree break in belt 5 between the tape drive motor and the speed converter assembly. S/N 22 did not meet its design life requirement of 750 hours. It had operated 658 hours.

4. Corrective Action:

The failure occurred during the unmanned period and an alternate recorder was selected.

On DOY 212 the SL-3 crew installed the spare tape recorder S/N 32.

5. Mission Effect:

Three hours of recorded data were lost and a replacement recorder was required.

Due to the failure of S/N 13 and an additional failure of S/N 22 on DOY 173, two replacement recorders (S/N 32 and 34) were flown up on SL-3. See Anomaly Report 159.

On SL-4 a tape recorder repair kit was flown up to replace the broken belts on S/N 13 and 22. This repair kit insured that the recording capability for the mission could be met if additional recorders failed.

ANOMALY REPORT 213

1. Statement of Problem:

Unintelligible voice dumps on Channel B.

On DOY 213, four days into the SL-3 mission, the first voice tape dumps using Channel B resulted in unintelligible (garbled) voice. Good voice dumps were obtained using the Channel A. The speaker volume on Channel B was noted lower than Channel A.

2. Investigative Action:

The crew performed a diagnostic procedure uplinked from the ground, whereby each of the redundant earphone amplifiers was disabled, one at a time, by opening the buffer amplifier circuit breakers 1 and 2 (see Figure 6-13). Subjective comments by the crew indicated the earphone amplifiers were operating satisfactorily because speaker volume decreased equally when each of the circuit breakers was turned to OFF. The crew then disconnected tape recorder 1 and recorded Channel B voice on tape recorders 2 and 3. This test resulted in garbled voice dumps from both recorders, indicating a failure of the Channel B tape recorder amplifier circuit.

During this period, the module contractor conducted tests on the ground, whereby the ALC power supply providing regulated power to the tape recorder amplifier and one of the two Channel B earphone amplifiers was varied. By reducing this supply voltage from the nominal plus 20 VDC to a range of 16 to 17 volts, the tape recorder amplifier circuit produced a low-frequency oscillation and garbled voice similar to problems encountered on the Skylab. At the same time the voice output at the speaker decreased by 1 dB.

3. Conclusions:

The cause of garbled audio as recorded on Channel B was a degraded power supply for the tape recorder amplifier within the ALC.

4. Corrective Action:

On DOY 213 the Channel A/Channel B configuration was reversed whereby intercom and air-to-ground communication was accomplished on Channel B and voice recorded on Channel A.

5. Mission Effect:

Except for the loss of the recorded voice on DOY 212, there was no impact on mission objectives. However, with only one tape recorder amplifier remaining for the SL-3 and SL-4 mission, an alternate mode of recording voice was investigated, resulting in the modification kit described in paragraph VI.B.2.b(3).

ANOMALY REPORT 214

1. Statement of the Problem:

VTR, S/N 4, failure on DOY 214.

The VTR lost the capability to play back using the prime and backup control modes. The failure permitted real-time transmission of portable color camera and ATM video, but precluded the playback of any recorded data. Playback of recorded video was the primary operational mode of television data retrieval.

2. Investigative Action:

VTR, S/N 4, failed on DOY 214 during playback to TEX. Several attempts to clear the malfunction by rewinding and re-initiating playback were unsuccessful. The MIL site reported no carrier modulation. The carrier frequency was read out as 2270.4595 MHz, which corresponded to a minus 1.04 VDC bias to the transmitter. These failure mode characteristics were indicative of a loss of output from the video demodulator printed circuit card in the electronics unit. This was verified by ground test. The backup initiation mode was attempted without success.

The inflight spare VTR, S/N 5, was installed on DOY 219 and checked out successfully. Because of CSM weight and room considerations, a procedure was sent up to have the crew remove the following printed circuit cards from the electronics unit for return:

A16 FM Equalizer
A17 Sync Limiter/Demodulator
A18 Video Limiter/Demodulator
A19 Video Output

The boards were removed on DOY 251 and subsequently returned. They were sent to RCA for failure analysis and were found to be physically and functionally nominal except A18 (video demodulator) which had low sensitivity. This condition produced the failure mode experienced.

A18 board failure was traced to a variable inductor, "WEE VL" L5, in a pulse-forming circuit which was open. This failure mode could not cause other failures in the VTR. Subsequent failure analysis revealed that failure was not attributable to circuit or electrical transient anomalies external to L5.

L5 was removed and replaced. All S/N 4 boards were system tested satisfactorily in S/N 8 VTR.

L5 and a control sample from the same lot were X-rayed and microsectioned. X-rays showed that both had inadequate wrap of coil wire around terminal wire, and that no solder filet was present at the junction. Microsectioning confirmed the X-ray. Prior to microsectioning, L5 was subjected to temperature shock. Cold temperature closed the junction and hot temperature reopened it.

3. Conclusions:

Failure was caused by poor component workmanship. The precipitating factor was a nonexcessive temperature rise caused by a long headwheel-motor run period before initiation of the playback period in which failure occurred.

4. Corrective Action:

The vendor, Nytronics, had performed the following:

100 percent test of coil functional parameters;
Statistical check of solder under 10X-micro;
Statistical external physical check;
Nonoperating temp cycle and soak - 100 percent;
100 percent test of functional parameters.

The manufacturer initiated action to change future procurement to require 100 percent solder checks under 10X-microscope and 100 percent temperature shock test rather than cycling.

Boards from S/N 4 and S/N 8 were X-rayed and put through temperature cycle of minus 10 to 60° C while operating. No anomalies occurred. Post test functional verification of the boards was performed. System test of the boards was performed in S/N 8 VTR.

Thirty-nine WEE VLs were installed on three boards. Only 25 WEE VLs on 4 boards were actually used on Skylab. The failed part, L5, and the control part were both from date/lot Code 7047. Thirty-six from this lot were X-rayed and 15 found questionable. There were 16 from this lot in S/N 4 and 8 VTRs.

The four boards were returned for the third manned period and a procedure generated to install them. Two replacement boards were also supplied for boards that had not been returned, but which had potentially faulty WEE VLs. These boards were not taken due to weight and volume constraints in the CSM. The four returned boards were never installed, since S/N 5 VTR performed nominally for the rest of the mission.

5. <u>Mission Effect</u>:

This failure did not impact mission video objectives or operating configurations. A listing of good operating practices for the VTR was sent to JSC and incorporated in operating procedures.

ANOMALY REPORT 215

1. Statement of Problem:

Intermittent operation of OWS low level Multiplexer B.

On DOY 215, OWS low level Multiplexer B started having intermittent failures with failures occurring at the following times:

04:57:50 through 05:13:32 GMT
12:28:15 through 15:01:36 GMT

No reason could be immediately determined as to why the multiplexer was operating intermittently.

The multiplexer continued intermittent operation throughout the remainder of the Skylab program.

2. Investigative Action:

No onboard troubleshooting was initially desired because such troubleshooting may have endangered the operation of other OWS multiplexers. Therefore, in investigating the problem the following analyses were performed:

a. A thermal analysis of the multiplexer including additional thermal testing at MDAC-E;

b. A detailed analysis of the telemetered data;

c. A design analysis of the hardware involved;

d. A correlation of multiplexer B cycling versus crew activity, position of the spacecraft, and time of day.

Based on the results of the above analysis, on DOY 250 it was decided that since there was an inherent risk involved in troubleshooting the intermittent failures of OWS Multiplexer B coupled with the fact that the measurements involved were of a noncritical nature, no additional troubleshooting would be performed. It was recommended, however, that if an additional multiplexer sustained a similar failure, the crew be instructed to open the circuit breaker that powered the failed multiplexer heater.

3. Conclusions:

Initial analysis of the data showed that the probable failure mode may have been that the multiplexer heater thermostat failed in the

ON position. However, as a result of the complete analysis of the tests and data described above, it was concluded that the most probable cause of the multiplexer failure was an internal multiplexer failure; more specifically, the nonredundant pulse steering diodes used on the counter module inputs. The exact nature of the failure was not determined.

4. Corrective Action:

Because the multiplexer was not redundant and could not be repaired, no corrective action was possible.

5. Mission Effect:

None. The measurements involved were not of a critical nature and were either not required or alternate measurements were available. The affected measurements are listed in Appendix A.

ANOMALY REPORT 219

1. Statement of Problem:

Teleprinter failed to print messages transmitted on DOY 219.

The crew reported the teleprinter paper had jammed and they had not received all of the messages transmitted during their sleep period.

2. Investigative Adtion:

Investigation by the crew revealed that the black paper drive roller in the teleprinter had come loose from its knurled bushing. The crew pushed the roller back on the bushing and the ground tried re-sending the messages. The roller again failed and the spare tele-printer was installed and used successfully.

Testing was performed which resulted in sending a repair procedure to the crew. This procedure wraps 1-inch tape around the shaft on each end of the bushing to keep the roller from working off the bushing.

3. Conclusions:

The teleprinter failed because the drive roller came loose from the drive shaft.

4. Corrective Action:

The failed teleprinter was replaced by the onboard spare on DOY 219. A repair kit was supplied on SL-4, but was not used.

5. Mission Effect:

The spare teleprinter onboard was not needed during the remainder of the Skylab mission and thus was not repaired.

ANOMALY REPORT 229

1. Statement of Problem:

The ICOM/XMIT switch on SIA 540 broke or DOY 229.

2. Investigative Action:

The crew reported that there was a broken ICOM/XMIT switch on the SIA. The spring force that returns the switch to the return-to-center OFF position was not present. Module contractor reported there was no previous history on this type failure.

3. Conclusions:

This was considered a random switch failure.

4. Corrective Action:

The SIA at location 540 was replaced with an onboard spare.

5. Mission Effect:

The replaced SIA returned the system to full capability. There was no impact on the mission or operational procedures.

ANOMALY REPORT 236-1

1. Statement of Problem:

Primary Time Reference System exhibited erratic behavior.

On DOY 236 at 21:21 GMT, the crew reported that the STS GMT display was erratic. Crew stated in a ten-second period that the GMT clock read the following values: 19:53:40, 22:49:48, 23:06:40, 19:52:46, and 22:49:40. The problem occurred after the crew installed the rate gyro six-pack.

2. Investigative Action:

The erratic readings appeared to be EMI related. A review was made of the ground and signal paths associated with the recently installed rate gyro six-pack. It was concluded that the installation of the rate gyro package did not cause the problem.

On DOY 237, the crew selected the secondary time correlation buffer which had no affect on the erratic displays.

On DOY 237, the secondary electronic timer was selected and the readings were normal.

The primary electronic timer was reselected on DOY 267 because of erratic secondary timer (see Anomaly Report 262). The primary timer functioned normally throughout the remainder of the mission.

3. Conclusions:

Cause of problem could not be determined and problem did not recur.

4. Corrective Action:

The secondary electronic timer was selected on DOY 237.

Mission Effect:

None. The primary timer functioned normally throughout the remainder of the Skylab mission.

ANOMALY REPORT 236-2

1. Statement of Problem:

Portable color camera, S/N 3002, failure.

On DOY 236, during EVA, S/N 3002 camera failed. The camera had been turned off for cooling and when turned back on failure occurred. Only the sync and vertical integral test signals were present and the color wheel was running. Later, when bringing the camera in, the crew reported an odd smell in the Airlock.

2. Investigative Action:

Significant failure related information acquired from STDN site video is tabulated below, chronologically.

GMT	REV	DATA SOURCE	CAMERA STATUS
16:45	1473	---	Locate on F8 handrail and turn on.
17:11	1473	GWM	VIT camera temperature = 85° F
17:45	1473	VAN	VIT camera temperature = 125° F
18:43	1474	GWM	VIT camera temperature = 140° F
18:49	1474	GWM	CDR expresses concern about camera heating.
19:25	1474	VAN	VIT camera temperature = 160° F
19:47	1474	MAD	(Station readout camera temperature = 156° F camera turned off)
20:41	1475	AUDIO	Camera turned on
20:45	1475	AUDIO DUMP	Camera failure sited by crew

VIT temperature signal showed rise above the 130° F operating redline at GWM in rev 1474. Readings continued to rise as shown in data from VAN and MAD. The latter station called in and the camera was turned off for a cooling period.

It had been the plan to use the camera on the EVA, based on thermal analysis with the VIT signal as a monitor. The analysis had shown that for this EVA, with 64 percent exposure and with the beta angle, location and time period, internal temperature would not rise above 125° F. VIT signal monitoring was marginal.

During thermal vacuum qualification testing, the vidicon glass envelope broke under differential expansion forces at 160° F. It was retested successfully to 130° F and this established the redline.

3. **Conclusions:**

The camera was returned and analysis revealed that the failure was caused by excessive heating.

4. **Corrective Action:**

No related corrective action was taken, but the portable camera was not used on EVA again.

5. **Mission Effect:**

Scheduled two camera television activities had to be revised for single-camera coverage for the remainder of the first manned mission.

ANOMALY REPORT 256

1. Statement of Problem:

AM tape recorder 3, S/N 28, failure.

On DOY 256 at 01:09 GMT, CDS reported during a data dump of tape recorder 3, S/N 28, that 90 percent of Experiment M092 data was bad. Sync dropouts occurred. Data were redumped over TEX, the next station pass, and over VAN, rev 1753, with the same results.

2. Investigative Action:

On DOY 256 at 04:59 GMT SF-4 data were recorded on S/N 28 and played back to the ground.

On DOY 260 the crew inspected S/N 28 and reported that the tape was off both capstans and idlers.

3. Conclusions:

S/N 28 had failed.

4. Corrective Action:

On DOY 256 at 11:17, tape recorder 3, S/N 28, was replaced with S/N 23.

On DOY 260 the crew cleaned the heads and rethreaded the tape and stowed S/N 28.

5. Mission Effect:

Loss of 3 hours (maximum) of medical experiment M092 data.

S/N 28 was available as a possible spare pending an onboard test after repair.

ANOMALY REPORT 256-2

1. Statement of Problem:

On DOY 256, the camera power cable, S/N 3002, and the camera monitor cable, S/N 3005, failed.

2. Investigative Action:

The camera and monitor were connected to the other cable set and performed nominally. Flexing of the bad cables yielded intermittent operation of the camera and monitor. The cables were returned for failure analysis, which confirmed failed electrical continuity.

3. Conclusions:

The cables experienced electrical continuity failures after normal usage.

4. Corrective Action:

Replacement cables were supplied for the third manned period.

5. Mission Effect:

There was no mission impact since a spare set of cables was available.

ANOMALY REPORT 260

1. Statement of Problem:

ATM TV monitor 1 failure.

On DOY 260, monitor 1 failed with no image or raster. Telemetry data showed no current being drawn when the monitor was turned on.

2. Investigative Action:

Failure simulation testing performed at MSFC showed that when power was switched on a normal monitor, a characteristic current transient always occurred on the input power line due to capacitor charging in the low-voltage power supply. This was not observed when the onboard unit was turned on and off.

3. Conclusions:

Because of the absence of the above described current transient, it was concluded that the diode before the low-voltage power supply had failed open.

4. Corrective Action:

Monitor 2 was used during the remainder of the second manned period. A new monitor was sent up for the third manned period. It was installed and operated nominally for the rest of the mission.

5. Mission Effect:

During the last 6 to 8 days of the ATM TV activity in the second manned period, the crew was constrained to one monitor. This imposed an undesirable procedural constraint on the crew.

ANOMALY REPORT 262

1. Statement of Problem:

   Secondary Time Reference System exhibited erratic behavior.

   On DOY 262 at 01:46 GMT the secondary TRS reset to 23:29 GMT. At 04:13 GMT the TRS reset to 23:20 GMT. Also, at 06:41 the TRS reset to 23:30. The crew verified that the telemetered time was the same as the BMT clock.

   On DOY 262 at 07:17 GMT the primary timer was selected and worked normally.

2. Investigative Action:

   The secondary timer was reselected on DOY 273:13:15 and reset at GMT midnight. The secondary timer operated successfully until DOY 324: 23:49. At that time the primary electronic timer was selected and remained on for the remainder of the mission. The problem could not be duplicated at the Skylab Test Unit in St. Louis. See Anomaly Report 236-1.

3. Conclusions:

   Cause of the problem could not be determined and it did not recur.

4. Corrective Action:

   None. Both systems are operating normally.

5. Mission Effect:

   None. Primary and secondary electronic timers are functioning normally.

ANOMALY REPORT 315

1. Statement of Problem:

AM Tape Recorder 3, S/N 23, fast forward malfunction.

On DOY 315 real-time command EXP 2/Data 2 FAST FORWARD COMMAND was sent for AM tape recorder 3 using the secondary DCS over MAD at 19:21:09 GMT. At 19:26:43 GMT, reset command EXP 2/Data 2 FAST FORWARD OFF, was sent and received and verified by the secondary DCS, but it did not deactivate the tape recorder.

2. Investigative Action:

The reset command was sent again at 19:28:04 GMT without positive results. The recorder was turned off with the RECORDER OFF command. At this point preliminary indications were that the secondary DCS was operating satisfactorily and the problem was isolated to relay module 3 and possibly only relay 19 (EXP 2/Data 2 FAST FORWARD).

The CMD to RESET was sent three times at the next station, HSK, at 315:20:05 GMT, and again it did not respond. The tape recorder was commanded to dump but it did not respond, indicating the FAST FORWARD CMD was still being held on the recorder. This confirmed the secondary DCS was functioning properly using real-time commands in other relay modules.

The next troubleshooting was performed at GDS at 315:22:18 GMT, when the primary DCS was turned on in parallel with the secondary DCS and the FAST FORWARD CMD was sent and it again did not respond. This indicated the problem was not the interface between the secondary DCS and relay module 3.

Further troubleshooting was attempted at BDS at 316:18:18 GMT where the FAST FORWARD RESET CMD was sent 20 times over a 4-minute period. It was noted on telemetry that the relay contacts were breaking on the SET side for approximately 100 ms, but they would then go back to the SET position. At this point, the problem appeared to be in relay module 3.

The next test was conducted over HSK at 316:19:22 GMT when the primary DCS was turned on and the secondary DCS was turned off. The FAST FORWARD CMD was sent without a resulting action. This test verified the problem was not associated with the DCS receiver/decoder, and was isolated to relay module 3.

Further troubleshooting was conducted over HSK at 316:20:59 when RESET and SET CMDs were sent to two spare relays located in relay module 3. The relays operated in a normal and proper mode. This isolated the problem to one relay (No. 19) located in relay module 3.

Troubleshooting continued at GDS at 317:00:50 GMT when the FAST FORWARD RESET CMD was sent and the relay responded and switched to the RESET position.

In addition to the above troubleshooting procedures, analysis was performed on similar relays (Sigma Series 32) to determine the probable cause of the relay malfunction. Analyses were conducted by MDAC-E using the same type relays (Sigma Series 32) of the same vintage. This analysis showed no history of test failures or previous flight failures. In addition, MSFC conducted an analysis on ten relays supplied by MDAC-E (from relay module S/N 121) and found loose particles of resin flux in each of these relays.

3. Conclusions:

As a result of the above troubleshooting and analysis, it was concluded that relay 19 in relay module 3 was contaminated between the armature and the permanent magnet latch bar on the reset side of the relay, not allowing sufficient motion for magnetic latch capture.

The contamination has apparently broken loose and moved sufficiently to allow RESET operation as a result of repeated command attempts.

4. Corrective Action:

At 317:00:50 GMT over GDS, a FAST FORWARD RESET command was sent and the relay responded properly, correcting the condition. The FAST FORWARD SET command (DSM 514) was deleted from all ground sites command computers, precluding sending that command again.

As a result of the above malfunction, MDAC-E modified two tape recorder "Y" cables to delete the fast-forward function. These cables were supplied to KSC for SL-4 stowage, but were not flown.

5. Mission Effect:

None.

ANOMALY REPORT 332

1. Statement of Problem:

SIA 131 failure.

On DOY 332, the crew was unable to establish two-way voice communication with the ground from the MDA SIA 131. The speaker was operating normally, but no voice signals from this SIA could be heard on the intercom loop or to the ground. Other SIAs were operating normally.

2. Investigative Action:

The crew ran an intercom test using the microphone on this SIA on both Channels A and B with negative results. However, good communications from this SIA were obtained using the headsets.

3. Conclusions:

The fact that good communication could be obtained from this SIA using the headset microphones, indicated a failure in the SIA microphone/amplifier section since the amplifier output and the headset microphone outputs are parallel.

4. Corrective Action:

SIA 131 was replaced by an onboard spare returning this station to its full capability.

5. Mission Effect:

There was no effect on mission configuration, objectives, or procedures.

ANOMALY REPORT 341

1. Statement of Problem:

WLC Vidicon Target Burn.

Vidicon target burns were observed to have occurred on DOY 341 and again on DOY 28. The first burn was just outside the occulting disc peripnery and was about 10 mm in diameter when viewed on the 8-inch monitor. A darker-than black horizontal band, the width of the burn, ran through the burn, across the entire raster. The amplitude of the burn on the waveform monitor was about 150 IEEEU. The second burn occurred just outside and above the first. It was about 20 mm in diameter. The attendant dark band was considerably lighter.

2. Investigative Action:

The crew was requested to initiate several grid discharge functions. During these, the spot defocused slightly but did not change in size or amplitude intensity. All video downlink data acquired were reviewed to ascertain if the low light level vidicon had been subjected to excessive light intensity. None was discovered in the data. The crew reported that occasionally they forgot to close the doors before turning on the vidicon and aligning the sun and occulting disc, but that they observed no high light levels immediately prior to the burns. Potential sources for the burns were examined by the vidicon supplier. The burns did not change in size or amplitude for the duration of the mission.

3. Conclusions:

It was concluded that the spots were caused by either vidicon target burn or contamination. In either case, no corrective action was available. The black band was caused by residual charge placed on a coupling capacitor by the high white level in the burned spots.

4. Corrective Action:

None.

5. Mission Effect:

Impact on the mission was slight in that data retrieval was lost from those areas burned.

ANOMALY REPORT 349

1. Statement of Problem:

AM low level multiplexer P excessively noisy measurements.

On DOY 349 at 13:42 GMT over Goldstone approximately 10 percent noise was observed on the low-level reference voltage (measurement M516) for low-level multiplexer P in the airlock module. Further investigation showed that measurements C0028, C0029, C0052, M301, M302, M303, and M304 were also noisy. All of these parameters are in MUX P and on the same second-level tier switch.

2. Investigative Action:

Review of data from station passes of TEX, MIL, and VAN prior to the GDS indicates the MUX P operation was normal. In an attempt to isolate the cause of the problem, data received at MDAC-E during Revs 3110 through 3116 were analyzed. This analysis failed to indicate a probable cause of the problem. As a result of the above troubleshooting, the most probable cause of the problem was analytically determined to be a change in turn-on characteristics of a second-level tier switch.

3. Conclusions:

The most probable cause of the noise is a change in turn-on characteristics of a second-tier switch common to all eight measurements.

4. Corrective Action:

None. Tier switch cannot be repaired or replaced.

5. Mission Effect:

Alternate measurements exist for six of the eight noisy measurements. C0028 and C0029 are temperatures for the proton spectrometer, which had previously failed.

NOISY MEASUREMENT	AVAILABLE ALTERNATE MEASUREMENT	ALTERNATE MEASUREMENT TITLE
M516-513	M517-513	LL MUX P 67 percent full-scale reference voltage
M301-512	M358-512	DCS 1 Verification Pulse
M302-512	M358-512	DCS 1 Verification Pulse

NOISY MEASUREMENT	AVAILABLE ALTERNATE MEASUREMENT	ALTERNATE MEASUREMENT TITLE
M303-512	M359-512	DCS 2 Verification Pulse
M304-512	K359-512	DCS 2 Verification Pulse
C0052-806	C0034-805	Internal CSM Docking Port Temperature

ANOMALY REPORT 357

1. Statement of Problem:

First eight channels of AM low-level Multiplexers and nine channels in programmer were noisy.

On DOY 357 at 06:09, the AM low-level multiplexers experienced noise on their 1.25 samples/second channels. This situation continued to 14:20 GMT and cleared up. The problem recurred on DOY 359 at 02:48 GMT and remained through the mission.

2. Investigative Action:

On DOY 357 the redundant interface box, programmers, and DC-DC converters were selected. The problem remained until 14:20 GMT.

On DOY 359, when the problem recurred, Instrument Groups 1 and 2, plus 5 VDC circuit [illegible], were cycled with no change.

STDN tapes [illegible] re analyzed in St. Louis and it was determined that all plus 3 mv [illegible] ererce channels (7 total) were lost. Most of the remaining 45 channels were varying from zero to full-scale or varying 25 percent of full-scale with correct readings about every 5 seconds. Usable data could be obtained through visual inspection of strip chart recordings of the affected measurements. Affected measurements are listed in Appendix A. Twelve channels were not used.

In the S[illegible] lab Test Unit in St. Louis and at the vendor, simulations were performed. It was determined that the most probable cause of the problem was a voltage propagated on the 3 mv (15 percent) reference line connected to all of the affected multiplexers and pro[illegible]ers.

3. Conclusions:

The most probable cause of the failure was a voltage propagated on the 3 mv reference line connected to all of the affected multiplexers and programmers.

4. Corrective Action:

No corrective action could be taken.

5. Mission Effect:

None of the affected measurements were critical to mission success. Most of the data could be determined from alternate measurements or by use of strip-chart recordings of the affected measurements.

ANOMALY REPORT 362

1. Statement of Problem:

TVIS, location 642, failure.

On DOY 362, the crew reported that while attempting to connect the camera cable at J3 of the TVIs, a pin broke and floated out.

2. Investigative Action:

MSFC formulated questions for the crew to discover: (1) if the camera cable connector could damage other TVISs; and (2) details on the nature of the failure. The crew's answer to the questions indicated that the camera cable connector was normal and connected nominally. Nothing more was learned on the nature of the failure until, during post mission debriefing, the crew indicated that the broken pin was round in shape. It was determined through reference to prior STU/STDN testing that replacement installation of the spare TVIS would not require readjustment of the preset TVIS gain.

3. Conclusions:

It was concluded that the broken pin in J3 was either the power pin or power return pin. The crew reported no significant problems with the J3 connector at other TVISs throughout the cluster.

4. Corrective Action:

The failed station was replaced with the inflight maintenance TVIS. No installation problems were experienced and the spare TVIS performed nominally for the duration of the mission.

5. Mission Effect:

None.

ANOMALY REPORT 17

1. Statement of Problem:

Airlock Module Quadriplexer corona problem.

On DOY 17 over Carnarvon during rev 3585, airlock module real-time data transmitter B was not functioning. Switching between transmitters B and C was unsuccessful in clearing the problem. Subsequent troubleshooting over GDS and VAN resulted in good real-time data using transmitter A2 and a good data/voice dump from transmitters B and C. Reconfiguration to the nominal operating mode at GDS at 018:00:35 appeared to have cleared the problem and real-time data from transmitter B were received.

The problem recurred on DOY 20 over HAW during rev 3629. The real-time data were switched to transmitter A2 and data were received. At the next site, VAN, real-time data were switched back to transmitter B and good data were received.

2. Investigative Action:

In response to a crew question submitted by MSFC on DOY 19, the crew reported on DOY 21 over Ascension during rev 3640 that the AM cabin relief valve 391 was in the open position, probably since the last EVA on DOY 363. Correlation of pressure data with execution of experiment M509 and AM transmitter B problems indicated that the valve was opening at relief pressure during execution of the experiment (M509) and probably causing corona in the AM quadriplexer.

3. Conclusions:

The most probable cause of RF carrier loss was corona, due to AM cabin relief valve no. 391 venting in the area of the AM quadriplexer, raising pressure in the quadriplexer to the critical pressure for corona to occur.

4. Corrective Action:

The crew closed AM cabin relief valve 391, on DOY 21 over Ascension during revolution 3640,

5. Mission Effect:

A minimal amount of data was lost due to the intermittent corona problem.

ANOMALY REPORT 018

1. Statement of Problem:

H-alpha 1 Vidicon image degradation.

On DOY 018, the crew reported that the H-alpha 1 image, as viewed on the monitor, had become degraded in contrast and resolution.

2. Investigative Action:

The H-alpha 1 vidicon was turned off while film camera electronics and telescope filter heater were left on. When the vidicon was turned back on, the image quality was nominal and remained so for about 15 minutes, when it again degraded. The crew reported that degradation could be observed on both monitors. An attempt was made to monitor this activity in the downlinked video, but due to the limited downlink bandwidth, H-alpha 1 resolution and contrast variations could not be adequately discerned.

3. Conclusions:

The H-alpha 1 film data were degraded.

4. Corrective Action:

The H-alpha 1 vidicon was turned off for a period before its scheduled use.

5. Mission Effect:

The only impact was change to operating procedure as noted in 4, above.

ANOMALY REPORT 019-1

1. Statement of Problem:

   AM tape recorder 1, S/N 32, failure.

   On DOY 019 over GWM during revolution 3613, tape recorder 1, S/N 32, began exhibiting motion monitor light problems. Subsequently, over VAN, during revolution 3615, S/N 32 began exhibiting data dropouts. Over VAN during revolution 3615, a 7-minute dump was expected, and only 4 minutes of data were received.

2. Investigative Action:

   Repeated attempts to record and play back over HAW on revolution 3615 indicated failure of S/N 32.

3. Conclusions:

   It was concluded that tape recorder S/N 32 had failed. S/N 32 had exceeded its 750-hour design life requirements by 700 hours.

4. Corrective Action:

   Over TAN on revolution 3615, the ground requested the crew to replace tape recorder S/N 32 with S/N 21. At AOS HAW during revolution 3616 on DOY 20, the crew informed the ground that S/N 32 had been replaced by S/N 21.

5. Mission Effect:

   Loss of S/N 32 resulted in a 2-hour loss of data from 19:22:37 to 20:00:37 GMT. Due to a sufficient number of spare tape recorders onboard, the AM record capability was not compromised.

ANOMALY REPORT 019-2

1. Statement of Problem:

On DOY 019 Audio System 6 Hz noise problem, the crew reported noise on Channel B occurring at a rate of approximately 6 Hz. This noise was present only on the intercom loop and was not heard on the downlink or tape recording circuit.

2. Investigative Action:

This problem was similar to a discrepancy that occurred for a short period on DOY 265. However, in that case the problem occurred in the CSM after undocking and was attributed to the CSM. The ground implemented a crew diagnostic procedure whereby the backup audio center was switched into the Channel B circuit. The problem still existed and troubleshooting of the earphone amplifiers of the Channel B was initiated. By opening and closing the two buffer amplifier circuit breakers sequentially, the noise disappeared when circuit breaker no. 1 was opened (see Figure 6-13).

3. Conclusions:

It was concluded that the noise source was originating from the secondary earphone amplifier in the Channel B audio load compensator.

4. Corrective Action:

Two options to minimize or eliminate the 6 Hz noise problems were presented to the crew:

a. Open audio buffer amplifier circuit breaker 1 and increase the volume settings on the SIAs when not recording.

b. Install emergency tape recorder voice adapter cable which, when utilized in conjunction with a lightweight CCU, would provide AM voice modulation direct to the tape recorder from an SIA.

5. Mission Effect:

As noted in Figure 6-13, opening circuit breaker 1 also disabled the remaining operational tape recorder amplifier of Channel A. Therefore, when voice recording was required it was necessary to go to the AM control panel and close this switch during voice recording. This procedure was tolerated since there were only 16 days left in the mission before final deactivation.

ANOMALY REPORT 030

1. Statement of Problem:

Portable Color Camera image spots.

Throughout the mission, in specific configurations, extensive spotting could be observed in the portable camera image. The extent of spotting appeared to increase with mission time. Spot visibility varied from faint to light gray to opaque. Spots were most objectionable in quantity and opacity toward the end of a manned period, at smaller lens apertures, at longer lens focal lengths, and in light scenes.

2. Investigative Action:

At the end of the first manned period, a returned camera was inspected. Contamination was found on the back of the color filter wheel and on the vidicon face plate. The material was described by JSC as being black, and of graphite-like consistency. The source of the contamination was not determined. The relation between lens aperture size and spot visibility was not understood since the contaminates were located on the focal plane. The inspected camera was cleaned and returned for the second manned period, during which it reacquired spots.

3. Conclusions:

The nature and source of the internal camera contaminants were not determined.

4. Corrective Action:

The crew had the capability of cleaning the vidicon faceplates, but were not instructed to do so.

5. Mission Effect:

Appendix E reflects those scenes in which undesirable spotting occurred.

ANOMALY REPORT 031

1. Statement of Problem:

   Portable color camera/VTS image softness.

   When the portable color camera was used with the S191 VTS, the resulting image lacked adequate resolution.

2. Investigative Action:

   JSC was contacted regarding the design and prelaunch test of the VTS optical adaptor for the camera. It was learned that the adaptor was not corrected for chromatic aberration. The lens position had been present for a wavelength in the visible spectrum that was to be optimum. Testing had been with a monochrome test chart.

3. Conclusions:

   It was not possible to focus the full spectrum of light reflected from the earth terrain using this adaptor.

4. Corrective Action:

   None. Data could be optimized by selecting only the color fields for which the adaptor was set. The image would be monochrome.

5. Mission Effect:

   TV system requirement to view through the S191 VTS was not satisfied. There was no change in configuration, operations, or procedures.

SECTION VIII. CONCLUSIONS AND RECOMMENDATIONS

A. Skylab I&C Systems

1. Data Acquisition System

a. ATM Data System. The ATM data system was operational through all phases of the Skylab mission after the launch phase. During the mission the data system processed 1.68×10^{12} data bits in real time and 9.0×10^{10} data bits of recorded data.

Operational problems involving the use of the ATM tape recorder were encountered early in the Skylab mission. The problems can be put into three categories, as follows:

(1) Tape recorder design constraints (see Appendix B),
(2) ATM coaxial switch failure on DOY 134, and
(3) Ground data processing.

To minimize the effect of the coaxial switch problem, a procedure was implemented that gave priority to the ATM data dumps by using the better of the two RF links. The data were dumped over a second ground site if the quality of the first data dump was unsatisfactory. As the actual operation of the ATM tape recorders became apparent, software changes in the ground data management system were incorporated that minimized the loss of data.

In future programs, care should be taken to insure close coordination between the flight data acquisition system designers, ground data management personnel, and the data users. More concentrated preflight testing must be performed to verify the total data link from the flight data acquisition system through the ground processing to the data user.

b. AM Data System. The Instrumentation System was operational during all phases of the Skylab mission and successfully acquired, multiplexed, and encoded selected vehicle systems, experiment and biomedical data. Data handling included telemetry downlink, crew displays, and PCM hardline for prelaunch use. During the mission, the system sampled and encoded 1164 input parameters and transmitted approximately 1.28×10^{12} bits of data in real time. An additional 1.0×10^{11} bits of data, excluding voice comments, were recorded on the AM tape recorders and transmitted during delayed time data dumps. Over 3650 delayed-time data dumps were successfully initiated. Following the resolution of early mission STDN PCM bit synchronization problems, ground recovery of all data was consistently good.

Although some discrepancies occurred during the mission with certain sensors, low-level multiplexers, and tape recorders, the system concept and design proved extremely feasible for meeting the mission requirements and for handling the large quantity of data involved.

Since corona was experienced at least twice in the manned missions by venting under the AM thermal shrouds, it would be desirable in the future to provide a vacuum gage near the RF equipment. The gage would indicate when the pressure is approaching the critical pressure, and vented RF equipment could be turned off before damage occurred. Also, one set of sealed RF equipment should be installed for operation in the critical pressure region. An example is the 2-watt transmitter for operation during launch.

More discrete and analog measurements are desirable to determine the status of the data system. Examples are tape recorder selection, transmitter selection and input currents, programmer and interface box selections, etc. These measurements would have assisted in anomaly resolution and monitoring of the system.

2. Command Systems

a. ATM Digital Command System. The ATM Digital Command System performance during the Skylab mission was successful. No failures were detected in the ATM DCS.

b. AM Digital Command System. The AM Digital Command System performance during the Skylab mission was successful except for one reported failure to execute a command message.

(1) Teleprinter Subsystem. This subsystem performed its intended function satisfactorily throughout the Skylab mission, providing the crews with retainable, hard copy messages. The frequent use of the teleprinter for sending hard copy updates of flight plans, crew procedures, etc, verified the desirability of such a device on a manned space mission.

(2) Timing Reference Subsystem. The TRS met all design goals during the Skylab missions. The system was operational throughout the mission and satisfactorily provided a time base for instrumentation, crew displays, and EREP.

3. Audio System. Although two failures occurred in the Audio System, its redundant design provided for maintaining an operating communications system. However, the need to open a circuit breaker to disable a noisy earphone amplifier (which also removed power from the remaining operational tape recorder amplifiers) approached a condition where the system would not meet its functional requirements. This occurred near the end of the last mission and the circuit breaker was closed only when voice recording.

Thirteen speaker intercom assemblies were located in Skylab to provide intercom between crew members and voice communication to the ground. However, the large number of SIAs contributed to the feedback problem which annoyed the Skylab crews. The installation of the antifeedback network assembly which reduced the system gain, proved to be very effective during the third Skylab manned mission.

Voice communication systems should be capable of operating with a minimum of man-machine constraints and provide good communication. The following recommendations should be considered for future programs:

a. Manned space programs involving the use of loud speaker transducers in a voice intercommunication subsystem must include the necessary design and testing to preclude the possibility of acoustical feedback from occurring during operation in the flight environment. The recommended techniques that could be implemented are:

(1) Limited use of loud speakers and/or compartment acoustical isolation between communication stations;

(2) Battery-operated wireless microphones, which include low sensitivity microphones retained on the crewman and held in close proximity to the voice source.

b. Hearing aids should be considered for crewmen during habitation of low pressure environments. These devices will compensate for the drop in acoustical efficiency of the atmospheric medium and, in effect, will allow loud speaker volumes to be reduced to a lower level and enable some voice conversations to take place without the aid of intercom systems.

4. Television Systems

a. TV system performance requirements and objectives were satisfied except for the following:

External viewing by means of the T027 was not accomplished due to use of the solar scientific airlock for sunshade deployment and loss of the universal extension mechanism due to experiment equipment malfunction;

Several two-camera scenarios were reduced to a single camera when one camera had failed;

Mission objectives were compromised, on occasion, by spotting in the portable color camera image;

Viewing through the S191 VTS was degraded due to lack of optical correction in S191 camera adapter.

b. Specific TV system components performed satisfactorily except as follows:

Two portable color camera failures occurred. One was due to faulty manufacturing contamination control, and the other was due to incorrect thermal analysis and inadequate ground monitor of the camera temperature;

One VTR failure occurred due to acceptance and use of a defective circuit component;

A TVIS failed. A power pin in the camera cable receptacle broke off. The crew also commented that an additional TVIS in the MDA for EREP equipment viewing would have been desirable;

Electrical continuity failures occurred in a camera power cable and a camera monitor cable;

ATM TV Monitor 1 failed. An open diode at the input was the most likely cause but was not verified.

None of the above equipment failures significantly degraded TV system performance. All were offset by installation of inflight maintenance spares or carry-up replacement units on the subsequent manned period.

c. Ground support elements at the STDN sites, MSFC, JSC, and St. Louis, performed satisfactorily. No significant anomalies were experienced except for the problem in monitoring the camera temperature signal during EVA.

d. Crew comments made at the end of manned periods were unanimous in conveying that setup and operation for the portable color camera scenarios was laborious and too complicated. The following changes should be considered in future TV system designs:

(1) Camera. Provide a wider angle lens than the 25 mm maximum provided by the zoom lens.

Design the basic camera lens controls (zoom, aperture, focus) to have factual identifiers such as size, shape, or surface texture.

Provide a means for simply and quickly determining the depth-of-field available for the lens settings selected.

Simplify the camera mount to provide more flexibility in selection of locations and greater ease in camera pointing.

Provide monitors having larger and full scan rasters for use in scenario composition and evaluation

Status lights should be provided on the camera to indicate that other system elements are properly configured to permit the desired onboard TV activity, such as video ecording or real-time downlink. Indication should include ground use of the VTR.

(2) VTR. Provide indications on the VTR of tape remaining and tape location (digital count).

Include an audible signal and/or indication in camera lights of when VTR end-of-tape occurs.

(3) TVIS. Provide VTR tape remaining indication. Provide VTR remote controls.

(4) Lighting. Provide a small, portable, diffused light source for subject fill lighting or background separation in close-up scenes.

The ATM monitor needed to have a high persistence phosphor screen for viewing the integrated XUV solar image.

e. The following discussion comprises recommendations toward enhancing future TV ground support activities.

Delayed time video data should have a time tag correlatable to GMT.

All video should be voice annotated by the crew to identify the image content and any significant system configurations. A microphone, conveniently worn or built into the camera, should be provided for this purpose.

Test patterns should be available for imaging at the start of any activity with any camera (color or monochrome). This would allow ground facilities to prepare for the video to follow and permit optimization of ground equipment adjustments.

All cameras should provide vertical interval test signals. These signals should include an identifier for the specific camera.

5. VHF Ranging. The VHF ranging system provided adequate CSM onboard verification that rendezvous maneuvers were being performed as planned. Its accuracy was adequate for manned rendezvous.

6. Skylab/STDN RF Interface. The small difference between the predicted telemetry link performance and actual mission performance is indicative that accurate analysis procedures were used. A significant input to this process was the ATM and AM antenna patterns measured at the antenna ranges.

Looking to future programs, the benefits of communicating at S-band frequencies or higher became apparent from the Skylab experience. Skylab program constraints dictated the use of available hardware from previous space programs, which were generally VHF equipment.

B. General Recommendations

1. Design Criteria. An attempt was made to assess the performance of the Skylab equipment and compare the equipment used from the previous programs with the equipment designed specifically for Skylab. Examples can be cited for both conditions. It can also be shown that some of the existing equipment from previous programs performed properly and that some of the newly designed and built equipment performed in accordance with the requirements. The Gemini tape recorder is an example of existing equipment that was deficient in a number of the requirements, which resulted in many modifications during the course of the program. Even though the AM tape recorders essentially performed in accordance with their predicted life, the end result was a recorder with a life of approximately 1000 hours and four failures during Skylab. The two ATM tape recorders, which were of a new design, operated for 3093 and 3969 hours, respectively, with no indication of deterioration at the end of the mission.

For future programs, equipment requirements must be evaluated very carefully with regard to performance and environmental criteria. If the results of the evaluation indicate major modifications or deficiencies in performance or in meeting environmental parameters, then it is recommended that a new design should be initiated.

2. Hardware Considerations

a. The three separate crews on Skylab all indicated by their repair operation that it is feasible to correct malfunctions on space vehicles. This was demonstrated on I&C equipment as follows:

Installation of four spare AM tape recorders and disassembly of the tape recorder to determine the cause of failure so a repair kit could be sent up on a subsequent launch.

Disassembly of the VTR and removal of printed circuit boards that were repaired on the ground. Several assemblies were returned to Skylab for installation, should another failure occur.

b. On future programs, the module approach to hardware design should be considered to enhance ease of component replacement (CL video tape recorder requires removal of over 70 screws to replace printed circuit boards). In addition, any monitoring system should be designed so the monitor points can be accessed and used by the crew to develop a workaround procedure, if required. Where failures occurred on nonrepairable items, the availability of wiring and connectors inside the vehicle enabled development of limited workaround procedures and kits. A modular approach to hardware design and ease of component replacement should be considered, especially on electromechanical devices.

c. The Zero "G" connector is an example of equipment design that resulted in good performance for connecting and disconnecting I&C equipment.

3. <u>Test Program</u>. Testing the interfaces of all modules and airborne equipment with corresponding ground equipment is a very important phase of the development. Extensive compatibility tests were conducted between the airborne data and command systems with the corresponding ground equipment. The lack of any command problems during the mission attests to the thoroughness of the prelaunch test program. Although a variety of interface problems were uncovered and resolved during ground tests, most of the problems encountered during the mission were primarily related to the ground computer's data processing capability. Testing between interfacing airborne and ground equipment is mandatory and should be extended through ground data processing. The peculiarities of the airborne data train should be thoroughly evaluated and tested with the ground equipment and its software programming to preclude development of problems.

APPENDIX A. ATM MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
T003-702	CMG No. 3 Wheel Speed	CMG No. 3 wheel speed transducer was the most probable failure. This measurement was backed up by the phase A, B, and C wheel currents; there was no mission impact.	DOY 148
C281-702	TEMP Z1 Rate Gyro	These measurements indicated off-scale high. Sufficient information was available to indicate that this was a true indication. Possibly caused by rate gyro heater failure. Mission impact: These gyros had a possible 6 percent scale factor error.	DOY 134
C441-702	TEMP X2 Rate Gyro		DOY 157
C442-702	TEMP Y2 Rate Gyro		DOY 135
C443-702	TEMP Z2 Rate Gyro		DOY 134
C464-702	TEMP Y3 Rate Gyro		DOY 135
C282-701	TEMP Pitch Rate Gyro Primary	Temperature off-scale high due to gyro characteristics (always coarse gain). Not enough information available to distinguish if heater or transducer failed. Mission impact: These gyros used for rate damping on spar. Manufacturer indicated no adverse effects on fluid or electronics for at least duration of Skylab.	DOY 151

APPENDIX A. AM MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
D209-505	MOL Sieve A $PPCO_2$ Inlet Pressure	Spikes up to 20 percent of full-scale; then decayed to normal in approximately 2 minutes at initiation of AM tape recorder No. 1 record command.	DOY 148
D210-505	MOL Sieve A $PPCO_2$ Outlet Pressure		
D213-505	MOL Sieve B $PPCO_2$ Inlet Pressure	Spikes up to 50 percent of full scale; then decayed to normal in approximately 2 minutes at initiation of AM tape recorder No. 1 record and playback command. Transient occurred coincident with bed cycling. Since the spikes were transient, the actual measurement values were distinguished, resulting in no detrimental effect on system operation.	
D213-505	MOL Sieve B $PPCO_2$ Inlet Pressure	Read 8-10 percent low because of 0 shift in sensor electronics or a sensor sensitivity change due to the active filter cartridge. Active cartridge with passive filter was installed on SL-3. Indicated 2.2 mmHg lower than D209. CO_2 measurement in experiment M171 could also be used as a zero calibration point. $PPCO_2$ may be read on MOL Sieve A. The MOL Sieve B inlet sensor can be used as an indication of increasing $PPCO_2$.	DOY 162

APPENDIX A. AM MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
D214-505	MOL Sieve B $PPCO_2$ Outlet Pressure	Read 11.1 mmHg; should have read about 2.3 mmHg Discrepancy due to depleted cartridge that will be replaced prior to MOL Sieve activation. No mission effect after cartridge replacement.	DOY 169
F214-534	Flow-PRI CLNT CTL Valve CVPB Out	During EVA, measurement went from nominal to an essentially zero reading with primary coolant loop on. Failed due to apparent contamination following procedure to free the vernatherm valve (mixing valve). System temperatures, pump ΔP, and split flow F212 related to flight data give sufficient data on system performance.	DOY 158
F206-534	Flow-Water System Flow Rate System 1	Read essentially zero with system 1 loop on, on DOY 170 during EVA. This was due to probable damage to bearings during final ground servicing at KSC. Adequate indication of system performance via temperature measurements.	DOY 170
F205-505	Interchange Duct Flow	Flow rate was decreasing.	DOY 237
K234-515	PIR-Loop Auto Switch Sense Group 1	Automatic switchover occurred twice. Sense group 1 has been inhibited. System was operating with sense group 2, only.	DOY 139
K931-534	EVA 1 Dump Δ Pressure	Did not alarm when LCG System pumps were turned on.	DOY 170

APPENDIX A. AM MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
K374-512	Coax Switch Position	TM indicated that switch stayed in "2-watt" position. Troubleshooting has verified that switch was cycling RF.	DOY 176
K509-509	Recorder 2 Tape Motion Monitor	Intermittent indication during playback. Operates properly in record mode. No mission impact. Recorder changed out on DOY 238.	DOY 222
M016-544	QCM No. 1 (+ x AMB) Fine Output	Output became erratic and then went below scale. Coarse output was still available. No mission effect.	DOY 232
M161-513	Regulator Bus 1 Fine Voltage	Spikes up to 16 percent of full-scale; then decayed to normal in approximately 2 minutes at initiation of tape recorder No. 1 record and playback.	DOY 148
M162-513	Regulator Bus 2 Fine Voltage	The above spikes were caused by a transient depression on the AM DC-DC converter +24 V output as a result of AM tape recorder No. 1 power up and playback. Sensor reliability is not affected. Since the spikes were transient and corresponded to specific AM tape recorder No. 1 operations, the actual measurement values could be distinguished, thereby resulting in no detrimental effect on system operation.	
M306-509 M308-509 M309-509	CWU EMER 5V Converter 1 CWU EMER 28V Converter 1 CWU EMER 28V Converter 2	Due to switching circuits in the C&W DC-DC converters, the parameters exhibited noise spikes of 6-8 percent for approximately 2 seconds. These spikes occurred 0-4 times per minute. Since the true voltage levels were highly distinguishable from the noise spikes, there was no detrimental effect on system operation.	DOY 146

APPENDIX A. AM MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
M310-509	CWU C&W 5V Converter 1		DOY 146 (Cont'd)
M311-509	CWU C&W 5V Converter 2		
M312-509	CWU C&W 28V Converter 1		
M313-509	CWU C&W 28V Converter 2		
M516-513	LL MUX P 15% FS Reference Voltage	These measurements were lost as a result of excessive noise generated in AM low level multiplexer P. These six measurements were also affected by low-level multiplexer failure on DOY 357.	DOY 349
M301-512	RCVR 1-DCS 1 Signal Strength Voltage		
M302-512	RCVR 2-DCS 1 Signal Strength Voltage		
M303-512	RCVR 1-DCS 2 Signal Strength Voltage		
M304-512	RCVR 2-DCS 2 Signal Strength Voltage		
C0052-806	External Docking Port Temperature		

APPENDIX A - AM MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
C001-531	ATM C&D Panel Inlet Coolant Temperature	The following measurements were lost as a result of erratic behavior of all AM low-level multiplexers.	DOY 357
C002-532	ATM C&D Panel Outlet Coolant Temperature		
C0028-806	Proton Spectrometer Detector Head Temperature		
C0029-806	Proton Spectrometer Electronics Package Temperature		
C227-515	Primary Coolant Module Inlet Temperature		
C228-515	Secondary Coolant Module Inlet Temperature		
C233-505	Primary Loop-Battery Module 1 Outlet Temperature		
C234-505	Secondary Loop-Battery Module 1 Outlet Temperature		
C235-505	Primary Loop-Battery Module 2 Output Temperature		
C236-505	Secondary Loop-Battery Module 2 Outlet Temperature		
C246-508	ATM Aft Tunnel Temperature		

APPENDIX A - AM MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
C266-538	Mole Sieve Dump Line 1 Temperature		DOY 357 (Cont'd)
C267-538	Mole Sieve Dump Line 2 Temperature		
K359-512	Event, DCS 2 Verification Pulse		
M109-524	SAS Array Group 1 Current		
M141-524	Battery 1 Current		
M142-524	Battery 2 Current		
M143-524	Battery 3 Current		
M144-524	Battery 4 Current		
M145-524	Battery 5 Current		
M146-524	Battery 6 Current		
M147-524	Battery 7 Current		
M148-524	Battery 8 Current		
M169-538	EPS Control Bus 1 Current		
M170-538	EPS Control Bus 2 Current		
M305-509	VHF Transponder/Receiver AGC		
M501-513	Programmer Low Level 15 Percent FS Reference Voltage		

APPENDIX A - AM MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
M502-513	Programmer Low Level 75 Percent FS Reference Voltage		DOY 357 (Cont'd)
M503-513	Low Level Multiplexer C 15 Percent FS Reference Voltage		
M505-513	Low Level Multiplexer E 15 Percent FS Reference Voltage		
M507-513	Low Level Multiplexer F 15 Percent FS Reference Voltage		
M509-513	Low Level Multiplexer G 15 Percent FS Reference Voltage		
M511-514	Instrumentation Bus A +24 VDC		
M512-514	Instrumentation Bus A -24 VDC		
M513-514	Instrumentation Bus A + 5 VDC		
M514-513	Low Level Multiplexer T 15 Percent FS Reference Voltage		
M518-513	Low Level Multiplexer S 15 Percent FS Reference Voltage		
M520-514	Instrumentation Bus B +24 VDC		
M521-514	Instrumentation Bus B -24 VDC		

APPENDIX A - AM MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
M522-514	Instrumentation Bus B +5 VDC		DOY 357 (Cont'd)
M527-513	Voltage, 67 Percent Volt Transistion (E)		
M528-513	Voltage, 67 Percent Volt Transistion (F)		
M529-513	Voltage, 67 Percent Volt Transition (G)		
M530-513	Voltage, 67 Percent Volt Transistion (H)		
M531-513	Voltage, 67 Percent Volt Transistion (I)		
M532-513	Voltage, 67 Percent Volt Transistion (J)		

APPENDIX A - OWS MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
G7011-433	Position SAS Wing 2, Section 1	These measurements were lost with the SAS wing 2. No mission effect.	DOY 134
G7012-433	Position SAS Wing 2, Section 2	Measurements identified with an asterisk (*) also are processed through low level multiplexer B and it became erratic in operation on DOY 215. No mission effect.	
G7013-433	Position SAS Wing 2, Section 3		
C7243-433*	TEMP SAS Wing 2, Section 1, Panel 3		
C7244-433	TEMP SAS Wing 2, Section 1, Panel 7		
C7245-433	TEMP SAS Wing 2, Section 2, Panel 3		
C7246-433	TEMP SAS Wing 2, Section 2, Panel 7		
C7247-433	TEMP SAS Wing 2, Section 2, Panel 9		
C7248-433	TEMP SAS Wing 2, Section 2, Panel 11		
C7249-433	TEMP SAS Wing 2, Section 3, Panel 3		

APPENDIX A. OWS MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
C7250-433	TEMP SAS Wing 2, Section 3, Panel 5		DOY 134 (Cont'd)
C7251-433	TEMP SAS Wing 2, Section 3, Panel 7		
C7252-433	TEMP SAS Wing 2, Section 3, Panel 11		
K7211-425	Event-SAS, Wing 2, Fair, Secured		
K7214-433	Event-SAS, Wing 2, Fair, Fully Deploy		
C7011-434*	TEMP MS Exterior 1	These measurements were lost with the meteoroid shield. No mission effect. Measurements identified with an asterisk (*) also were processed through LL multiplexer B, which became erratic in operation on DOY 215. No mission effect.	DOY 134
C7012-434	TEMP MS Exterior 2		
C7013-434	TEMP MS Exterior 3		
C7014-434*	TEMP MS Exterior 4		
C7015-434	TEMP MS Exterior 5		
C7016-434*	TEMP MS Exterior 6		
C7017-434	TEMP MS Exterior 7		
C7018-434	TEMP MS Exterior 8		
G7032-426	Position MS Deployment Link Position 5 Forward		
K7010-434	Event-MS, Tension Strap 1, Secured		
K7011-434	Event-MS, Tension Strap 2, Secured		

APPENDIX A. OWS MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
K7012-434	Event-MS, Tension Strap 3, Secured		DOY 134 (Cont'd)
F7000-436	Flow-VCS Duct 1	Flowmeter failed. There was minimal mission effect because the onboard display was still operating.	DOY 147
F7001-440	Flow-VCS Duct 2	Flowmeter was showing a flowrate of approximately 10.0 cfm lower than onboard display. A further degradation was observed on DOY 228. The mission effect was minimal because the onboard display was still operating.	DOY 143
P7002-440 P7001-440	Biomed-VABD Depth Dose Rate VABD Skin Dose Rate	These measurements showed cyclic bursts of noise of up to 12 percent. The data from the sensor could still be reduced. Mission effect was minimal. The measurements cleared with the departure of CSM (SL-2), and noise returned with SL-3. Analysis indicates CSM IMU heater was the cause of the noise.	DOY 166
M7058-440	TCS, Duct Heater Current, Element 2-2, 2-4, 3-4	This measurement showed shifts in data up to 14 percent of full-scale (3.2 amps) when the heater was not energized. These shifts have been correlated to activity on OWS Bus 2. There was no known mission effect.	DOY 167
D7112-436	Press-Habitation Area, Low Range, Sensor 2	Exhibited a response lag in relation to other transducers monitoring depressurization. Measurement was degraded; however, effect on mission was minimal because there were several other monitors for habitation area pressure.	DOY 174

APPENDIX A. OWS MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
D7125-442	Press-Water System, Waste Management Compt Dump Line (Onboard Display)	This measurement failed off-scale high. There was minimal mission effect because: A. Purge fitting could be used to verify dump problem was clear. B. System evacuation times were increased for deactivation drying. C. Evacuation of the WMC water system for activation was not critical because there was no concern about entrained gas in wash water.	DOY 210
D7104-442	Waste Processor Exhaust Inlet Press (Onboard Display)	D7104 appeared to read high. D7103 waste processor exhaust outlet and D7106 waste tank pressure were used to correct D7104.	DOY 210

APPENDIX A. OWS MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
	"THE FOLLOWING MFASUREMENTS HAVE BEEN INTERMITTENT DUE TO MULTIPLEXER B ANAMOLY"		
C7049-449	TEMP-TCS, EXP COMPT WALL, No. 3	Use Measurement C7045	DOY 215
C7051-443	TEMP-TCS, WDRM Wall, No. 4	Use Measurement C7047	
C7095-407	TEMP-TCS, Common Backing Insul No. 3	Use Measurement C7091	
C7097-407	TEMP-TCS Common Backing Aft Compt Face No. 3	Use Measurement C7092	
C7101-410	TEMP-TCS, FWD Dome Ext HP1, No. 1	No direct alternate measurement available: performance evaluation was based on sensors C7163 and C7107 plus other as applicable.	
C7105-404	TEMP-TCS, FWD Joint Ext, No. 1	No direct alternate measurement available: Performance evaluation was based on C7103 plus others as applicable.	
C7113-410	TEMP-TCS, FWD Dome Ext., No. 4	Use Measurement C7112	
C7115-403	TEMP-PRI CKT T/C in CLNT	Use as an alternate C7114	
C7161-432	TEMP SAS Wing 1, Section 3, Panel 3	Use Measurements C7146 to C7151, and C7240, and C7242	
C7162-410	TEMP-TCS, FWD Dome EXT, No. 1	No direct alternate measurement available: performance evaluation was based on C7100 and C7106 plus others as applicable.	

APPENDIX A. OWS MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
C7164-438	TEMP-VCS, Duct 1 Outlet Gas	No direct alternate measurement available; performance evaluation was based on remaining sensors, C7176, C7307, C7308, C7144, C7256.	DOY 215 (Cont'd)
C7166-438	TEMP-VCS, Duct 3 Outlet Gas		
C7172-436	TEMP-VCS, Duct 1 Inlet Gas		
C7184-411	TEMP-TCS, FWD Skirt Int. No. 2	No direct alternate measurement available; performance evaluation was based on remaining sensors.	
C7186-426	TEMP-TCS, FWD Skirt T/S No. 2	Use Measurement C7178	
C7254-436	TEMP-VCS M/C Inlet Gas, Recirculation	No direct alternate measurement available; performance evaluation was based on measurements C7176, C7307, C7308, C7144, C7256	
C7255-438	TEMP-VCS, COMPT Inlet Gas	Use Measurement C7144	
C7282-436	TEMP-FMS, Food STOR FRZR COMPT-2	Use as an alternate C7281	
C7284-443	TEMP-FMS, Food STOR FRZR COMPT-1	Use as an alternate C7285	
C7286-436	TEMP-VCS, Food STOR FRZR COMPT-1	Use as an alternate C7285	
C7295-436	TEMP-RS, SEC CKT FS FRZR CLNT OUT	Use measurement C7288	
C7298-443	TEMP-FMS, Food FRZR Chiller COMPT	Use as an alternate C7296	

APPENDIX A. OWS MEASUREMENT ANOMALIES

NUMBER	TITLE	ANOMALIES AND MISSION EFFECT	DATE OF ANOMALY
C7300-403	TEMP-RS, SEC CKT Radiator Surface	Use measurement C7299	DOY 215 (Cont'd)
C7302-436	TEMP-RS, SEC LP REG HTR CLNT In	Use measurement C7008	
M7037-411	Volt-DAS, Low Level MUX B, REF HI	Not required if multiplexer inoperable.	
M7038-411	Volt-DAS, Low Level MUX B, REF LO	Not required if multiplexer inoperable.	

APPENDIX B. ATM TAPE RECORDERS

The following test was conducted to determine the amount of data that would be lost each time the ATM tape recorders reversed direction and switched heads. The testing was performed to determine: the amount of real time data lost; the amount of data lost due to PCM ground station operation; and the amount of data recoverable by normal means, such as use of the frame synchronization signals for data control in the PCM ground station.

1. Results. The results of the subject test are as follows:

a. Data Missing From Tape. The amount of real-time data lost was: (see Figure B-1)

(1) Turnaround "Z" - 10.75 seconds;
(2) Turnaround "Y" - 7.25 seconds.

The amount of data lost did not vary from one data reduction to another.

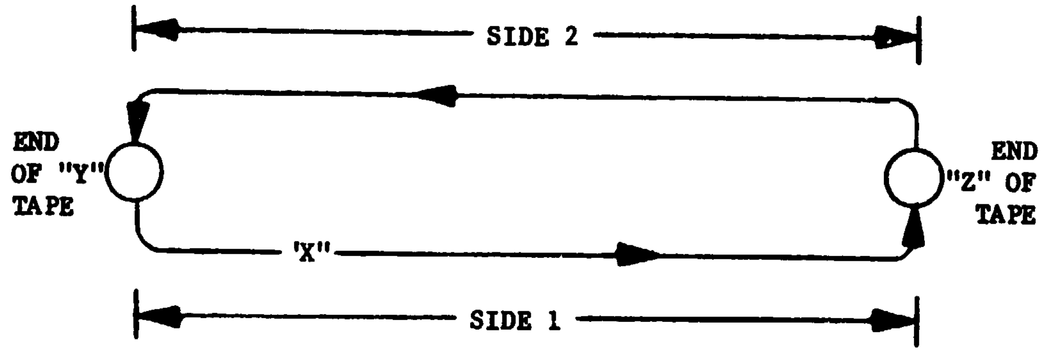
b. Decommutation Data Loss. An additional data loss occurs due to loss of synchronization in the PCM ground station decommutator. This additional loss was found to be:

(1) Turnaround "Z" - 2.50 seconds;
(2) Turnaround "Y" - 12.50 seconds.

2. Data Loss. An analysis of the results of the above-mentioned test reveals the following:

a. Data Missing From Tape. The differences in the amount of data lost at the two turnarounds (turnaround "Y" versus turnaround "Z") is attributed to mechanical properties of the recorder, such as tape leader length, difference in spring tensions, etc. This phenomenon was also observed in a similar test of the prototype recorder.

b. Decommutation Data Loss. Analysis indicates that the amount of data lost due to loss of PCM ground station synchronization will vary from approximately 0.5 to approximately 15 seconds, assuming the PCM ground station is programmed for maximum synchronization sensitivity. The large variation is due to the asynchronous operation of the tape recorder within the ASAP system. The best-case and worst-case conditions for this type of data loss are described in the following paragraphs (see Figure B-2).



POINT "X" - START AND END OF RECORDING
POINT "Y" - END OF TAPE, OR TURNAROUND
POINT "Z" - END OF TAPE, OR TURNAROUND

NOTE: A typical recording would start on Side 1 at point "X", proceed to "Z" at which point the tape reverses direction and the heads are switched. The recording then continues on Side 2 until "Y", at which point the tape again reverses direction and the heads are switched. The recording then continues to point "X", at which time the tape would be stopped. Operating in the playback mode is identical except that a higher tape speed is used to accomplish playback in 5 minutes.

FIGURE B-1. TYPICAL RECORD PLAYBACK SEQUENCE

(1) Best Case Condition. In this case, the data missing from the tape segment A-B ends just prior to master frame synchronization time. Therefore, the decommutation data loss is a minimum, one or two frames (0.25 to 0.5 second, assuming two frame synchronization words are required prior to master frame synchronization, typical for most PCM ground stations).

(2) Worst Case Condition. In this case, the data missing from the tape segment A-B ends during the last frame of data or immediately after master frame synchronization time. Data in the segment, B-C, will be unusable due to the loss of master frame synchronization, which will be recovered at D, the next master frame synchronization time. Master frame synchronization occurs at 15-second intervals.

3. Data Recovery. Tests further indicate that certain portions of data lost due to decommutation, as explained above, are recoverable. The basis for this is that some of the data lost due to loss of PCM ground station synchronization (decommutation data loss) can be recovered because the PCM bitstream is normal after the missing portion (point B in Figure B-2). Frame synchronization will be acquired in

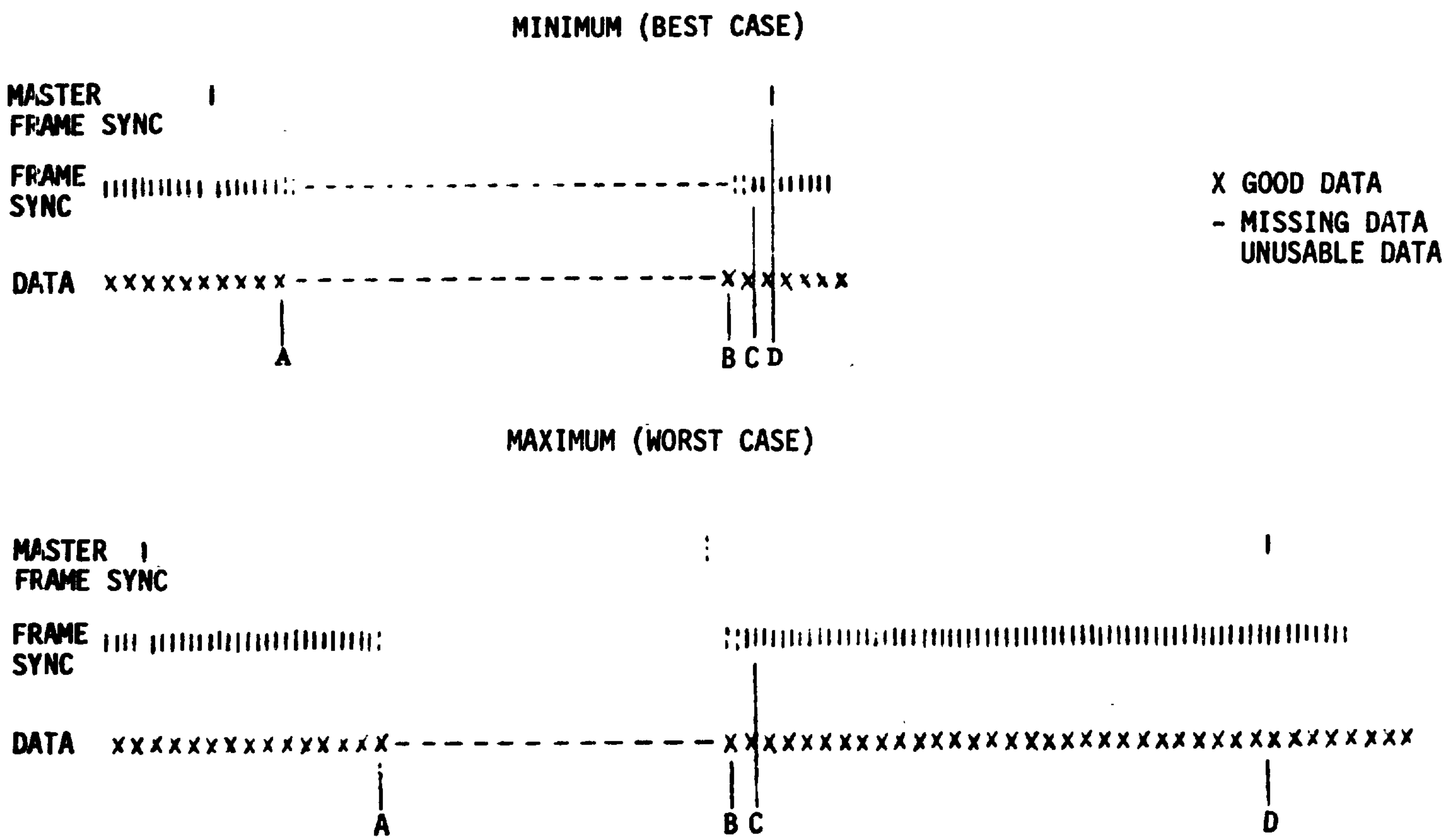


FIGURE B-2. DECOMMUTATION DATA LOSS.

approximately two frames after point B. The method for data recovery depends on the sample rate and is described below.

a. Sample Rates Greater than Four Samples per Second. Measurements in this category are sampled a minimum of once per frame and require frame synchronization only for decommutation; therefore, this type data can be fully recovered after adquisition of frame synchronization by programming frame synchronization for control of the PCM decommutator. This type of data recovery can be performed in real time. Data contained in the frames after point B, but prior to acquisition of frame synchronization, can be recovered in the same manner as data of less than 4 sps and is described below.

b. Sample Rates Less than Four Samples per Second. Measurements in this category are sampled less than once per frame and may be sampled only once per master frame. Master frame synchronization is required for normal data reduction. Special processing would include manual data reduction techniques such as reverse data reduction (playing an instrumentation tape in the reverse direction with the appropriate programming of the PCM decommutator) or techniques using the appropriate computer programs.

APPENDIX C - AM/STDN TELEMETRY SIGNAL STRENGTHS

SITE	REV	LINK A AVG	LINK A RANGE	LINK B AVG	LINK B RANGE	LINK C AVG	LINK C RANGE	MAXIMUM ELEVATION (DEGREES)
		SIGNAL STRENGTH LEVELS (-dBm)						
GDS	314	88	82-103	87	82-89	87	82-89	53
	315	95	90-107	-	-	-	-	20
	316	100	92-107	-	-	-	-	8
	317	97	91-107	-	-	-	-	9
GDS	385	97	87-104	-	-	-	-	53
	386	95	90-100	-	-	-	-	20
	387	100	95-107	-	-	-	-	8
	388	99	94-103	-	-	-	-	9
	389	101	96-105	95	87-97	90	83-101	30
	390	102	97-107	93	88-98	96	92-98	9
GDS	613	-	-	92	90-102	-	-	24
	614	-	-	97	92-99	-	-	8
	615	-	-	99	91-107	-	-	8
	616	-	-	95	90-99	-	-	23
	617	-	-	95	87-100	-	-	38
GDS	770	-	-	99	92-103	-	-	10
	771	-	-	99	95-107	-	-	7
	772	-	-	97	92-103	97	91-103	17
	773	-	-	92	85-99	-	-	71
	774	-	-	97	94-100	-	-	6
GDS	811	-	-	92	85-99	-	-	56
	812	-	-	94	90-103	93	90-99	20
	813	-	-	101	95-104	-	-	8
	814	-	-	99	90-105	-	-	9
	815	-	-	97	88-101	-	-	30
	816	-	-	95	90-99	-	-	26
GDS	1180	104	99-107	96	89-104	95	89-100	85
	1181	-	-	95	89-100	93	87-95	16
	1182	-	-	98	94-103	-	-	7
	1183	-	-	99	95-104	-	-	11
	1184	-	-	95	92-99	-	-	45
	1185	100	97-105	90	84-98	93	86-97	17
GDS	1422	-	-	93	86-100	-	-	64
	1423	-	-	97	94-101	-	-	13
	1424	-	-	98	95-101	-	-	7
	1425	-	-	97	92-104	-	-	13
	1426	-	-	90	84-99	-	-	61
	1427	-	-	99	93-104	-	-	12

APPENDIX C (continued)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK A AVG	LINK A RANGE	LINK B AVG	LINK B RANGE	LINK C AVG	LINK C RANGE	MAXIMUM ELEVATION (DEGREES)
GDS	1521	103	100-106	93	88-100	95	90-98	44
	1522	-	-	95	92-99	-	-	22
	1523	-	-	99	95-104	-	-	8
	1524	-	-	98	95-100	-	-	9
	1525	-	-	95	88-99	-	-	26
	1526	-	-	96	92-98	96	90-98	32
GDS	1762	-	-	98	95-104	-	-	16
	1763	-	-	95	88-99	-	-	48
	1764	-	-	96	92-99	-	-	12
	1765	-	-	98	94-102	-	-	7
	1766	-	-	96	91-102	-	-	15
	1767	-	-	93	86-99	-	-	81
	1768	-	-	97	94-104	-	-	9
GDS	1975	-	-	100	92-<107	-	-	14
	1976	-	-	94	88-100	-	-	56
	1979	-	-	95	92-105	-	-	13
	1980	-	-	93	85-101	-	-	70
	1981	-	-	96	93-103	-	-	11
GDS	2288	-	-	95	90-100	-	-	40
	2289	-	-	95	92-100	-	-	24
	2290	-	-	100	94-104	-	-	9
	2291	-	-	99	96-103	-	-	9
	2292	-	-	95	91-100	92	89-98	24
	2293	-	-	93	89-100	-	-	36
GDS	2472	-	-	99	89-107	-	-	8
	2473	-	-	94	85-103	-	-	85
	2474	-	-	98	90-<107	-	-	16
	2475	-	-	100	93-105	-	-	7.5
	2476	-	-	93	88-99	-	-	11
	2477	-	-	90	84-101	-	-	42
	2478	-	-	93	90-97	92	89-98	18.5
GDS	2714	-	-	95	92-100	-	-	22
	2715	-	-	93	88-98	-	-	35
	2716	-	-	98	94-103	-	-	10
	2717	-	-	99	95-<107	-	-	8
	2718	-	-	98	91-<107	-	-	18
	2719	-	-	91	85-98	90	82-96	69
	2720	-	-	98	94-102	-	-	6

APPENDIX C (continued)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK A AVG	RANGE	LINK B AVG	RANGE	LINK C AVG	RANGE	MAXIMUM ELEVATION (DEGREES)
GDS	3098	-	-	95	83-101	-	-	82
	3099	-	-	96	91-100	-	-	16
	3100	-	-	97	94-103	-	-	7
	3101	-	-	97	95-101	-	-	10
	3102	103	98-106	94	87-98	-	-	40
	3102	103	98-<107	95	91-102	96	92-105	19
GDS	3566	104	99-<107	97	92-101	94	89-107	21
	3567	-	-	94	89-100	-	-	40
	3568			100	90-105	-	-	11
	3569			100	93-107	-	-	7.5
	3570			100	91-<107	-	-	16.5
	3571			94	85-<107	-	-	73
GDS	3751	-	-	93	88-102	-	-	50
	3752	-	-	95	91-<107	-	-	21.5
	3753	-	-	100	92-<107	-	-	8
	3754	-	-	97	92-<107	-	-	9
	3755	-	-	94	90-103	-	-	28
GDS	3907	-	-	96	91-103	-	-	34.5
	3908	-	-	95	91-103	-	-	26
	3909	-	-	94	92-101	-	-	9
	3910	-	-	97	92-104	-	-	8.5
	3911	-	-	97	89-107	-	-	24
	3912	-	-	94	91-102	-	-	42

APPENDIX C (continued)

		SIGNAL STRENGTH LEVELS (-dBm)						MAXIMUM
		LINK A		LINK B		LINK C		ELEVATION
SITE	REV	AVG	RANGE	AVG	RANGE	AVG	RANGE	(DEGREES)
TEX	270	92	87-105	-	-	-	-	26
	271	98	87-<107	-	-	-	-	21
	272	95	92-<107	-	-	-	-	2
	274	99	92-<107	99	92-103	100	96-101	3
	275	91	88-104	-	-	-	-	22
	276	95	85-105	95	92-100	99	95-105	24
TEX	497	-	-	98	91-102	-	-	18
	498	-	-	93	90-99	92	89-101	30
	502	-	-	95	91-99	-	-	16
	503	104	98-<107	92	89-105	91	87-99	37
	554	-	-	95	90-100	-	-	24
	555	-	-	92	90-100	-	-	23
	556	-	-	95	92-98	-	-	2.5
TEX	558	-	-	102	91-105	-	-	3
	559	-	-	93	89-99	95	89-100	21
	560	-	-	101	91-110	-	-	27
TEX	1449	-	-	-	-	91	84-103	81
	1450	-	-	-	-	98	94-103	10
	1453	-	-	-	-	98	94-105	7
	1454	-	-	89	77-99	95	84-102	58
	1455	-	-	-	-	-	-	9
TEX	1824	-	-	95	92-100	98	92-107	19
	1832	-	-	95	92-100	-	-	20
	1833	-	-	92	88-100	-	-	26
	1837	-	-	95	89-105	-	-	18
TEX	2698	-	-	95	92-98	98	92-103	10
	2699	-	-	93	82-103	91	82-96	60
	2700	-	-	105	94-<107	-	-	12
	2703	-	-	103	92-<107	-	-	6
	2704	-	-	97	87-<107	98	87-107	43
TEX	2897	-	-	99	91-107	-	-	3.3
	2898	-	-	90	81-97	90	83-97	76
	2899	-	-	104	97-<107	-	-	10
	2902	-	-	97	90-<107	-	-	6.5
	2903	-	-	93	84-97	-	-	53
	2904	-	-	95	92-103	-	-	9.2

APPENDIX C (Continued)

SITE	REV	LINK A AVG	LINK A RANGE	LINK B AVG	LINK B RANGE	LINK C AVG	LINK C RANGE	MAXIMUM ELEVATION (DEGREES)
		SIGNAL STRENGTH LEVELS (-dBm)						
TEX	3356	-	-	95	91-98	-	-	2.5
	3357	-	-	95	87-107	-	-	22.5
	3358	-	-	93	87-98	91	87-98	22.5
	3366	-	-	95	92-103	-	-	17
	3367	-	-	95	87-104	94	87-105	31
TEX	3722	-	-	92	87-<107	-	-	32
	3723	-	-	99	92-<107	-	-	4
	3725	-	-	96	90-104	-	-	-
	3726	-	-	96	91-<107	-	-	15.5
	3727	-	-	92	88-<107	-	-	41
TEX	3891	-	-	95	91-107	-	-	4.5
	3892	-	-	93	85-<107	-	-	85
	3893	-	-	99	92-<107	-	-	10
	3896	-	-	96	89-107	-	-	7.5
	3897	-	-	97	77-<107	-	-	60
	3898	-	-	105	94-<107	-	-	8.5

APPENDIX C (Continued)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK A AVG	RANGE	LINK B AVG	RANGE	LINK C AVG	RANGE	MAXIMUM ELEVATION (DEGREES)
MIL	1108	-	-	-	-	97	92-104	70
	1109	-	-	-	-	100	92-105	12
	1110	-	-	-	-	100	95-<107	-
	1112	-	-	-	-	98	95-107	8
	1113	103	97-107	95	91-102	95	90-99	61
	1114	104	101-107	93	87-97	95	89-99	8
MIL	1453	-	-	97	93-99	-	-	4
	1454	-	-	94	85-96	-	-	31
	1455	-	-	96	91-102	95	90-100	19
MIL	1562	105	101-<107	98	93-104	96	92-98	5
	1563	-	-	94	84-101	-	-	86
	1568	-	-	91	82-101	87	77-95	81
	1569	-	-	98	93-101	97	93-100	6
MIL	1932	-	-	90	87-100	-	-	38
	1933	107	103-<107	97	90-105	98	93-103	17
	1934	-	-	107	95-<107	-	-	5
	1936	-	-	96	92-100	-	-	5
	1937	-	-	89	86-98	-	-	35
	1938	-	-	95	92-98	93	89-100	14
MIL	2528	-	-	96	91-102	95	92-102	6
	2534	-	-	89	83-98	-	-	89
	2535	-	-	99	96-102	-	-	5
MIL	2940	-	-	95	93-101	97	93-100	4.5
	2941	-	-	92	82-98	89	84-95	86
	2942	-	-	95	91-100	96	90-99	10
	2945	-	-	95	93-104	-	-	9
	2946	103	93-<107	90	83-100	95	88-98	75
MIL	3310	102	90-107	86	81-92	91	85-95	60
	3311	-	-	97	91-<107	97	93-102	12.5
	3314	-	-	95	92-101	-	-	6.5
	3315	98	88-104	88	84-95	88	83-93	53
	3316	-	-	97	94-<107	-	-	10

APPENDIX C (continued)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK A AVG	RANGE	LINK B AVG	RANGE	LINK C AVG	RANGE	MAXIMUM ELEVATION (DEGREES)
MIL	3664	-	-	102	97-<107	-	-	2.5
	3665	-	-	92	86-102		-	59
	3666	-	-	100	93-<107	-	-	13.5
	3667	-	-	100	92-<107	-	-	—
	3669	-	-	95	92-100	-	-	7
	3670	-	-	95	84-100	-	-	52.5
MIL	3906	-	-	100	92-<107	-	-	22.5
	3907	-	-	95	87-104	-	-	25
	3908	-	-	102	94-106	-	-	3.5
	3911	-	-	95	89-105	-	-	24.5
	3912	-	-	95	89-<107	-	-	24.5

APPENDIX C (continued)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK A AVG	LINK A RANGE	LINK B AVG	LINK B RANGE	LINK C AVG	LINK C RANGE	MAXIMUM ELEVATION (DEGREES)
BDA	454	-	-	94	90-98	-	-	11°
	455	101	95-110	90	84-97	-	-	59
	456	101	95-107	94	90-98	-	-	10
	457	-	-	93	90-105	-	-	4
	458	-	-	90	84-97	-	-	7
	459	-	-	87	84-95	-	-	28
	460	-	-	90	84-95	92	94-99	24
BDA	1223	-	-	101	92-<107	95	89-107	4
	1224	-	-	-	-	95	89-101	15
	1225	-	-	-	-	93	90-96	64
	1226	-	-	-	-	92	85-98	4
BDA	1448	-	-	98	91-104	98	95-105	10
	1449	-	-	95	88-<107	-	-	67
	1450	-	-	97	92-101	-	-	11
	1451	-	-	-	low elevation pass		-	
	1452	-	-	98	96-99	-	-	6
	1453	-	-	94	89-102	-	-	26
	1454	-	-	97	89-<107	-	-	27
BDA	1747	-	-	91	82-<107	-	-	61
	1748	101	97-107	96	88-99	95	89-99	16
	1749	-	-	97	91-102	-	-	4
	1750	-	-	97	91-103	-	-	5
	1751	-	-	95	91-99	-	-	17
	1752	98	94-103	92	85-97	90	84-95	52
BDA	2087	-	-	103	98-<107	-	-	6
	2088	-	-	92	80-104	90	80-99	80
	2089	-	-	95	92-104	-	-	14
	2090	-	-	97	93-101	-	-	4
	2091	-	-	99	95-107	-	-	5
	2092	-	-	96	90-103	-	-	20
	2093	-	-	95	88-98	-	-	40
BDA	2116	-	-	95	92-103	-	-	26
	2117	-	-	95	89-101	-	-	27
	2118	-	-	98	92-107	-	-	6
	2119	-	-	99	92-107	-	-	3
	2120	-	-	97	93-102	-	-	10
	2121	-	-	95	86-99	-	-	62
	2122	-	-	97	93-107	-	-	8

APPENDIX C (continued)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK A AVG	LINK A RANGE	LINK B AVG	LINK B RANGE	LINK C AVG	LINK C RANGE	MAXIMUM ELEVATION (DEGREES)
BDA	2187	-	-	93	90-103	-	-	24
	2188	-	-	93	88-102	-	-	29
	2189	-	-	96	91-104	-	-	7
	2190	-	-	98	92-105	-	-	3
	2191	-	-	98	92-103	-	-	10
	2192	-	-	92	85-98	-	-	58
	2193	-	-	98	95-105	-	-	11
BDA	2301	-	-	92	88-98	93	88-98	60
	2302	-	-	98	95-103	-	-	16.5
	2303	-	-	100	95-104	-	-	4.5
	2304	-	-	99	92-103	-	-	4.5
	2305	-	-	97	92-103	-	-	17
	2306	-	-	93	88-103	-	-	54
	2307	-	-	97	92-102	-	-	5
BDA	2686	-	-	98	92-<107	96	92-100	9
	2687	-	-	102	95-<107	-	-	3.5
	2688	-	-	98	95-<107	-	-	7.3
	2689	-	-	95	91-104	-	-	34
	2690	-	-	96	93-<107	-	-	
BDA	3068	-	-	94	89-102	-	-	43
	3069	103	98-<107	96	90-104	96	93-105	18
	3070	-	-	98	94-103	-	-	4.5
	3071	-	-	98	92-104	-	-	4
	3072	-	-	97	92-101	-	-	14
	3073	-	-	91	85-101	-	-	74
BDA	3366	-	-	96	88-105	-	-	27
	3367	-	-	96	89-<107	-	-	26
	3368	-	-	99	89-<107	-	-	6
	3369	-	-	99	93-105	-	-	3
	3370	-	-	97	93-105	-	-	10.5
	3371	-	-	93	84-104	-	-	66
	3372	-	-	99	96-<107	-	-	9
BDA	3777	-	-	93	81-<107	-	-	10
	3778	-	-	96	90-<107	-	-	19.5
	3779	-	-	99	91-<107	-	-	5
	3780	-	-	96	92-<107	-	-	4
	3781	--	-	96	91-<107	-	-	14.5
	3782	-	-	93	86-<107	-	-	74

APPENDIX C (concluded)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK A AVG	LINK A RANGE	LINK B AVG	LINK B RANGE	LINK C AVG	LINK C RANGE	MAXIMUM ELEVATION (DEGREES)
BDA	3905	-	-	97	93-<107	-	-	6.5
	3906	-	-	96	86-<107	-	-	88
	3907	-	-	96	90-<107	-	-	13
	3908	-	-	99	91-105	-	-	4
	3909	-	-	99	94-107	-	-	5.5
	3910	-	-	100	89-<107	-	-	22

APPENDIX D ATM/STDN TELEMETRY SIGNAL STRENGTHS

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK NO. 1 AVG	LINK NO. 1 RANGE	LINK NO. 2 AVG	LINK NO. 2 RANGE	MAXIMUM ELEVATION (DEGREES)
GDS	314	84	80-87	87	82-95	53
	315	-	-	92	87-97	20
	316	-	-	97	95-105	8
	317	-	-	92	89-107	9
GDS	385	93	85-98	93	83-95	53
	386	95	90-98	95	92-98	20
	387	94	91-103	97	93-103	8
	388	98	90-107	97	92-107	9
	389	94	85-98	92	88-99	30
GDS	613	95	92-99	95	90-101	24
	614	95	92-98	97	95-100	8
	615	97	91-101	95	90-104	8
	616	97	90-<107	92	87-107	23
	617	96	87-<107	92	90-95	38
GDS	770	100	97-<107	97	95-107	10
	771	100	92-<107	101	92-<107	7
	772	100	95-<107	98	95-<107	17
	773	97	88-101	95	83-103	71
	774	103	97-105	96	91-101	6
GDS	811	95	85-103	92	83-<107	56
	812	100	91-<107	95	92-<107	20
	813	103	95-<107	97	91-102	8
	814	103	98-107	95	90-100	9
	815	98	95-107	94	87-105	30
	816	94	90-103	92	84-105	26
GDS	1180	97	89-100	93	89-102	85
	1181	93	89-100	93	90-98	16
	1182	97	94-101	97	90-100	7
	1183	100	91-107	97	95-104	11
	1184	96	92-104	95	92-98	45
	1185	90	86-97	92	84-97	17
GDS	1422	101	89-107	90	78-97	64
	1423	100	92-107	97	90-105	13
	1424	100	94-104	98	93-104	7
	1425	99	91-<107	96	90-104	13
	1426	94	84-99	93	78-107	61
	1427	99	92-101	96	90-99	12

APPENDIX D (continued)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK NO. 1 AVG	RANGE	LINK NO. 2 AVG	RANGE	MAXIMUM ELEVATION (DEGREES)
GDS	1762	96	91-107	96	91-105	16
	1763	95	86-103	91	88-98	48
	1764	102	97-107	93	90-100	12
	1765	102	97-<107	96	92-99	7
	1766	103	97-<107	96	90-103	15
	1767	95	88-107	92	82-105	81
	1768	100	95-<107	95	91-102	9
GDS	1975	98	90-<107	94	87-<107	14
	1976	91	82-98	90	81-97	56
	1979	97	90-<107	94	90-102	13
	1980	92	85-101	90	84-97	70
	1981	93	89-100	93	90-98	11
GDS	2288	96	87-107	91	87-95	40
	2289	102	92-<107	93	90-97	24
	2290	103	94-<107	97	93-105	9
	2291	99	90-<107	99	94-<107	9
	2292	97	92-103	92	88-104	24
	2293	94	87-102	92	86-103	36
GDS	2472	104	100-<107	94	85-98	8
	2473	92	85-101	90	78-105	85
	2474	99	93-106	96	88-105	16
	2475	102	97-<107	99	92-<107	7.5
	2476	101	91-<107	95	90-105	11
	2477	97	88-<107	90	84-98	42
	2478	97	90-105	90	85-95	18.5
GDS	2714	93	88-97	97	90-102	22
	2715	95	88-<107	90	87-98	35
	2716	99	95-104	100	93-103	10
	2717	100	97-105	99	93-105	8
	2718	97	92-101	97	92-102	18
	2719	100	90-103	92	83-104	69
	2720	96	92-98	103	97-<107	6
GDS	3098	95	87-<107	90	85-98	82
	3099	100	92-<107	95	89-105	16
	3100	103	95-<107	98	91-<107	7
	3101	98	93-104	96	90-<107	10
	3102	92	87-103	93	88-107	40
	3103	95	92-99	95	89-103	19

APPENDIX D (continued)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK NO. 1 AVG	RANGE	LINK NO. 2 AVG	RANGE	MAXIMUM ELEVATION (DEGREES)
GDS	3751	91	83-103	92	84-102	50
	3752	93	91-104	97	91-<107	21.5
	3753	99	92-104	97	91-<107	8
	3754	99	90-<107	97	92-<107	9
	3755	98	90-<107	94	90-107	28
GDS	3907	95	89-<107	91	85-103	34.5
	3908	98	88-<107	90	83-99	26
	3909	97	93-<107	99	88-105	9
	3910	98	90-<107	100	91-<107	8.5
	3911	99	92-<107	99	87-<107	24
	3912	95	91-101	94	92-101	42
GDS	3566	93	89-100	102	93-<107	21
	3567	101	85-<107	93	87-103	39.5
	3568	98	93-103	98	92-101	11
	3569	100	92-107	100	92-<107	7.5
	3570	98	90-107	98	87-<107	16.5
	3571	100	95-<107	90	83-102	78
GDS	1521	97	89-101	90	80-97	44
	1522	99	93-105	94	90-103	22
	1523	102	95-<107	100	93-<107	8
	1524	103	97-<107	98	94-107	9
	1525	99	90-107	92	86-102	26
	1526	95	88-105	91	85-97	32

APPENDIX D (continued)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK NO. 1 AVG	RANGE	LINK NO. 2 AVG	RANGE	MAXIMUM ELEVATION (DEGREES)
TEX	270	92	84-100	92	84-100	26°
	271	92	89-102	92	89-102	21
	272	95	91-100	95	91-102	2
	274	-	-	100	96-<107	3
	275	-	-	102	90-<107	22
	276	90	88-<107	92	87-107	24
TEX	497	95	87-<107	100	93-107	18
	498	95	85-<107	95	87-105	30
	502	91	87-101	91	87-103	16
	503	106	87-<-107	90	82-94	37
TEX	554	95	86-105	95	85-105	24
	555	105	93-<107	94	88-100	23
	556	92	88-95	98	96-100	2.5
	558	95	90-102	95	90-102	3°
	559	90	85-100	90	85-100	21°
	560	100	90-<107	92	87-105	27°
TEX	1449	98	90-105	87	81-98	81°
	1450	98	92-102	98	94-105	10
	1453	98	90-<107	97	91-104	7
	1454	93	85-104	90	82-100	58
	1455	96	91-98	96	91-98	9
TEX	1824	92	88-105	91	85-98	19
	1832	89	85-95	92	85-98	20
	1833	98	92-107	92	88-105	26
	1837	98	92-105	92	89-100	18
TEX	2698	92	90-95	93	88-104	10
	2699	95	81-<107	90	80-98	60
	2700	96	91-<107	94	89-<107	12
	2703	96	92-<107	98	93-<107	6
	2704	99	88-107	93	86-103	43
TEX	2897	98	90-<107	95	87-102	3.3
	2898	90	78-96	90	78-98	76
	2899	96	92-100	98	95-<107	10
	2902	96	90-<107	97	91-<107	6.5
	2903	93	81-<107	92	81-<107	53
	2904	93	91-98	95	92-102	9.2
TEX	3356	95	92-98	95	91-99	2.5
	3357	95	89-<107	90	87-103	22.5
	3358	98	92-<107	90	82-99	22.5
	3366	95	90-105	98	91-<107	17
	3367	98	92-105	94	87-101	31

APPENDIX D (continued)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK NO. 1 AVG	RANGE	LINK NO. 2 AVG	RANGE	MAXIMUM ELEVATION (DEGREES)
TEX	3722	92	86-106	100	87-<107	32
	3723	107	92-<107	106	100-<107	4
	3725	99	92-106	97	91-106	-
	3726	99	87-<107	100	88-<107	15.5
	3727	95	88-<107	90	83-107	41
TEX	3891	96	92-<107	95	88-107	4.5
	3892	91	88-<107	88	81-105	85
	3893	96	89-<107	97	90-<107	10
	3896	91	88-106	93	89-107	7.5
	3897	91	78-<107	91	78-<107	60
	3898	99	89-<107	95	89-107	8.5

APPENDIX D (continued)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK NO. 1 AVG	RANGE	LINK NO. 2 AVG	RANGE	MAXIMUM ELEVATION (DEGREES)
MIL	1108	94	88-102	90	85-100	12
	1109	94	88-103	91	87-97	—
	1110	98	94-101	94	91-97	29
	1112	98	94-107	93	90-97	61
	1113	97	94-104	97	88-101	8
	1114	95	87-104	92	90-97	
MIL	1453	98	94-107	101	93-106	4°
	1454	98	87-107	90	85-100	31
	1455	96	88-104	97	92-105	18
MIL	1562	105	98-<107	96	92-105	5°
	1563	92	84-104	92	79-97	86
	1568	98	85-105	89	82-97	81
	1569	98	95-101	95	92-100	6°
MIL	1932	94	83-101	92	83-100	38
	1933	96	91-104	95	89-100	17
	1934	99	96-102	96	92-100	5
	1936	102	96-105	95	92-99	5
	1937	99	91-<107	91	85-98	35
	1938	95	90-101	93	88-100	14
MIL	2528	100	93-<107	100	92-<107	6
	2534	92	80-104	87	80-98	89
	2535	<103	98-<107	94	90-100	5
MIL	2940	103	94-<107	92	86-100	4.5
	2941	89	80-101	86	76-98	86
	2942	96	93-101	97	92-<107	10
	2945	97	93-104	98	93-102	9
	2946	90	82-98	90	77-100	75
MIL	3310	96	90-100	96	89-102	60
	3311	99	95-<107	97	88-107	12.5
	3314	99	95-<107	94	89-97	6.5
	3315	96	84-<107	89	81-97	53
	3316	99	96-<107	94	89-104	10
MIL	3664	100	92-<107	99	91-<107	2.5
	3665	92	83-<107	91	77-107	59
	3666	96	89-100	93	89-103	13.5
	3667	100	96-103	102	96-<107	-
	3669	100	92-106	94	91-102	7
	3670	97	86-<107	91	78-102	52.5

APPENDIX D (continued)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK NO. 1 AVG	LINK NO. 1 RANGE	LINK NO. 2 AVG	LINK NO. 2 RANGE	MAXIMUM ELEVATION (DEGREES)
MIL	3906	91	86-<107	92	87-104	22.5
	3907	95	87-<107	93	85-100	25
	3908	99	92-<107	95	90-101	3.5
	3911	91	86-96	92	86-98	24.5
	3912	95	87-102	92	85-<107	24.5

APPENDIX D (continued)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK NO. 1 AVG	LINK NO. 1 RANGE	LINK NO. 2 AVG	LINK NO. 2 RANGE	MAXIMUM ELEVATION (DEGREES)
BDA	454	96	92-103	95	93-98	11°
	455	93	84-104	93	83-104	59
	456	98	92-107	99	93-105	10
	457	98	93-103	96	93-100	4
	458	96	92-100	97	93-103	7
	459	89	87-95	92	84-98	28
	460	97	87-108	92	87-104	24
BDA	1223	95	90-101	95	92-100	4
	1224	95	91-104	98	95-104	15
	1225	95	92-98	95	93-97	64
	1226	95	90-100	90	85-95	4
BDA	1448	100	95-<107	98	95-102	10
	1449	102	95-<107	93	85-<107	67
	1450	98	95-101	97	95-100	11
	1451	Low Elevation Pass				
	1452	102	93-<107	99	95-<107	6
	1453	95	88-107	98	89-105	26
	1454	96	87-<107	95	89-100	27
BDA	1747	95	85-<107	87	81-94	61
	1748	100	92-<107	97	93-107	16
	1749	105	98-<107	94	92-104	4
	1750	105	98-<107	98	94-107	5
	1751	99	93-<107	96	89-107	17
	1752	93	87-100	93	86-103	52
BDA	2087	103	99-107	97	91-105	6
	2088	92	81-101	90	81-101	80
	2089	96	93-99	96	94-99	14
	2090	100	97-103	100	97-104	4
	2091	100	92-104	99	93-104	5
	2092	98	92-100	100	93-105	20
	2093	92	87-100	96	87-100	40
BDA	2116	94	91-100	95	88-98	26
	2117	96	89-100	95	89-99	27
	2118	100	98-107	97	94-104	6
	2119	101	98-105	101	92-<107	3
	2120	98	95-100	97	94-100	10
	2121	89	85-97	89	84-101	62
	2122	101	95-105	95	92-98	8

APPENDIX D (continued)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK NO. 1 AVG	LINK NO. 1 RANGE	LINK NO. 2 AVG	LINK NO. 2 RANGE	MAXIMUM ELEVATION (DEGREES)
BDA	2187	97	90-103	92	89-103	24
	2188	93	87-<107	94	88-100	29
	2189	100	92-<107	97	90-<107	7
	2190	105	99-<107	100	94-<107	3
	2191	100	95-107	102	95-<107	10
	2192	91	83-98	89	82-99	58
	2193	100	95-<107	100	95-107	11
BDA	2301	100	90-<107	93	85-100	60
	2302	103	96-<107	100	95-<107	16.5
	2303	105	95-<107	102	97-<107	4.5
	2304	100	93-<107	99	92-<107	4.5
	2305	101	92-<107	97	92-<107	17
	2306	95	84-<107	90	84-98	54
	2307	97	94-<107	99	95-<107	5
BDA	2686	100	97-103	97	95-105	9
	2687	103	100-<107	100	96-<107	3.5
	2688	98	96-<107	100	91-<107	7.3
	2689	102	91-<107	94	88-98	34
	2690	98	90-107	96	89-103	20
BDA	3068	94	87-<107	91	87-101	43
	3069	92	89-<107	93	84-101	18
	3070	97	90-<107	-	-	4.5
	3071	98	91-<107	-	-	4.0
	3072	97	93-101	93	89-104	14
	3073	89	83-98	91	81-105	74
BDA	3366	98	87-106	95	86-106	27
	3367	98	91-<107	97	88-<107	26
	3368	105	95-<107	98	95-<107	6
	3369	98	91-<107	105	97-<107	3
	3370	98	91-<107	97	95-<107	10.5
	3371	95	84-<107	95	85-97	66
	3372	105	95-<107	103	89-<107	9
BDA	3777	90	83-<107	94	84-<107	10
	3778	97	84-<107	100	93-<107	19.5
	3779	99	87-105	100	92-<107	5
	3780	97	94-107	100	93-<107	4
	3781	95	89-<107	94	87-<107	14.5
	3782	94	86-107	91	83-107	74

APPENDIX D (concluded)

SITE	REV	SIGNAL STRENGTH LEVELS (-dBm) LINK NO. 1 AVG	RANGE	LINK NO. 2 AVG	RANGE	MAXIMUM ELEVATION (DEGREES)
BDA	3905	101	97-<107	98	91-<107	6.5
	3906	96	84-<107	96	87-<107	88
	3907	104	91-<107	101	96-<107	13
	3908	101	91-<107	99	95-<107	4
	3909	100	92-<107	96	92-<107	5.5
	3910	95	88-<107	93	87-<107	22

APPENDIX E - COLOR VIDEO QUALITATIVE SUMMARY

RATING CODE: 4 = EXCELLENT 2 = FAIR OR SATISFACTORY
3 = GOOD 1 = POOR

DOY	SCENE TITLE	* TV NO	* DUMP NUMBER	NOISE DROP OUTS	CONTRAST	SPOTS AND BLEMISHES	SMEAR	RESOLUTION & DEPTH OF FIELD
145	RENDEZVOUS	41	1-4	3	2	2	3	2
147	PARASOL DEPLOY	-	5-1	3	2	3	3	2
147	OWS SURPRISE NO. 1	-	5-8	1	2	3	3	2
147	OWS SURPRISE NO. 2	-	5-11	3	2	2	3	2
148	LBNP	6	8-2	2	4	3	3	4
149	MEAL PREPARATION	2	9-11	3	3	2	3	3
150	EATING	3	10-5,9	2	2	3	3	3
151	ATM-C&D CONSOLE	13	13-2	2	3	3	3	3
152	SL-500	-	14-3	2	4	3	3	3
154	EREP-1	11	17-3	3	1	2	3	3
154	OUT THE WINDOW	37	19-4	3	3	1	3	2
157	PRE-EVA	-	26-3	3	2	2	3	2
158	EVA	-	28-3	4	3	2	3	2
160	LBNP	6	33-3	2	2	2	3	2
162	ERGOMETER	9	36-1	2	1	3	3	2
163	LBNP	7	40-1	3	3	1	3	2
163	EREP/VTS	29-1	41-3	2	3	1	2	1
164	M551-METALS MELTING	24	45-1	3	3	1	3	3
164	EREP/VTS	29-2	46-2	2	2	1	3	2
165	M131 MOTION SENSITIVITY	20-1	51-3	3	2	1	3	2
165	M131 MOTION SENSITIVITY	20-2	51-4	2	2	1	3	2
166	ED31 BACTERIA & SPORES	17	55-4	3	3	2	3	3
167	TOUR-CREW QUARTERS	25	60-3	3	3	3	3	2
168	TOUR-MDA/AM/OWS	26	63-3	2	2	2	3	2
168	SLEEP/TRASH/SHOWER	15	64-3	3	3	2	3	2
168	SLEEP/TRASH/SHOWER/SHOES	5	66-3	3	3	2	3	3
170	EVA	-	73-3,5	3	2	2	3	2

*See "Skylab TV Ops Book" of JSC, Houston, Texas

APPENDIX E - (continued)

DOY	SCENE TITLE	TV NO	DUMP NUMBER	NOISE DROP OUTS	CONTRAST	SPOTS AND BLEMISHES	SMEAR	RESOLUTION & DEPTH OF FIELD
209	RENDEZVOUS	41	1-1	4	3	4	3	3
209	RENDEZVOUS	41	1-3	2	3	4	3	3
212	FISH	53	3-1	2	3	3	3	2
213	EATING	3A	4-1	2	2	2	3	3
213	EATING	3	5-3	2	3	2	3	3
214	EATING	3	6-3	1	2	2	3	2
214	LBNP	6	7-2	2	2	4	3	3
215	EREP	11	8-3	3	3	4	3	2
215	EREP	11	9-3	3	2	3	3	3
216	VTR REPAIR	-	11-4	3	3	4	3	3
217	S183 (UV PANORAMA)	23	12-3	4	3	4	3	4
219	C&D CONSOLE	13	16-3	1	2	4	3	3
220	ERGOMETER	9	19-1	2	1	4	3	2
221	ROTATING CHAIR M131	20	24-1	3	3	3	3	3
222	EXERCISE (BALL & CORD)	61	27-1	2	3	3	3	2
222	EXERCISE (BALL & CORD)	61	27-2	3	3	3	3	3
224	INVITRO IMMUNOLOGY	58	37-1	3	3	4	3	2
225	FILM THREADING	12	41-2	3	3	4	3	2
240	OWS TOUR	26	102-1	3	3	4	3	3
240	OWS TOUR	26	102-2	1	2	4	3	3
241	HURRICANE BRENDA	-	105-1	2	4	1	3	4
242	ENTERTAINMENT CENTER	14	109-2	2	3	4	3	3
242	TOUR	26	109-4	3	3	4	3	4
242	S183 UV PANORAMA	23	112-2	2	3	4	3	3
243	S183 UV PANORAMA	23	115-2	3	4	4	3	4
251	WATER BUBBLE	53	144-5	3	3	3	3	3
251	EREP FILM CHANGE	12	146-2	3	3	4	3	3
252	TOUR MDA	-	148-2	3	3	4	3	3

APPENDIX E - (continued)

DOY	SCENE TITLE	TV NO	DUMP NUMBER	NOISE DROP OUTS	CONTRAST	SPOTS AND BLEMISHES	SMEAR	RESOLUTION & DEPTH OF FIELD
253	EREP (AFRICA)	-	156-2	3	3	1	3	4
254	TV INVENTORY	26	160-4	2	3	2	3	3
255	C&D CONSOLE	26	167-4	2	3	4	3	2
256	SUITED M509	36	173-2	1	4	4	3	4
257	WILBER FORCE PENDULUM	53	177-3	2	3	1	3	3
225	M509	36	42-1	3	4	4	3	2
227	SPECIMEN MASS MEASUR-ING DEVICE WATER GUN	1	46-1	2	3	4	3	2
		1	46-3	3	3	4	3	4
227	AM TAPE RECORDER REPAIR	-	49-2	3	4	4	3	3
228	EATING	3	51-2	3	3	4	3	3
229	M509	36	58-1	3	4	4	3	4
230	EVA PREPARATION	43	63-1	3	3	4	3	3
230	OUT THE WINDOW	30	65-2	2	3	1	3	4
230	HAIRCUT	-	68-2	3	3	3	3	3
232	HURRICAN BRENDA	-	69-1	2	3	2	3	4
233	OUT THE WINDOW	63	75-5	3	3	4	3	2
233	OUT THE WINDOW	63	75-5	3	3	3	3	2
234	WARDROOM	-	81-2	2	3	4	3	3
236	EVA	43	88-1	2	3	3	3	4
237	EVA	43	90-4	2	2	3	4	2
238	VTS-EREP	11	93-7	2	1	1	3	1
238	SPIDER WEB	59	96-1	3	2	3	3	2
239	M509	-	98-1	2	3	4	3	3
261	SHAVING	16	188-2	3	3	4	2	3
262	TAPE RECORDER	-	195-1	2	3	4	3	3
				3	3	4	3	3
321	ACTIVATION	64	1-1	2	2	3	2	2
321	ACTIVATION	64	1-2	1	1	1	1	1
323	COOLANT SERVICING	72	2-2	2	2	3	3	3

APPENDIX E - (continued)

DOY	SCENE TITLE	TV NO	DUMP NUMBER	NOISE DROP OUTS	CONTRAST	SPOTS AND BLEMISHES	SMEAR	RESOLUTION & DEPTH OF FIELD
329	S192 ALIGNMENT	83	4-2	1	2	3	3	2
330	S192 ALIGNMENT	83	4-3&4	1	2	3	3	2
331	IVA TELECAST	77	9-2	1	2	3	3	2
333	MEAL	3	14-1	2	3	4	4	3
333	MEAL	3	14-3	3	4	4	4	4
335	S183 UV PANORAMA	23	21-1	3	4	4	4	4
335	S183 UV PANORAMA	23	21-3	2	3	3	3	3
335	S183 UV PANORAMA	23	23-1	2	3	3	3	3
336	OWS AIR SCREEN CLEAN	65	24-2	2	2	3	3	2
338	WATER SAMPLING	33	28-2	1	1	2	2	2
339	SCIENCE HIGHLIGHTS	28	32-2	3	2	3	3	3
2	COMET SURVEY TOUR	-	104-7	3	4	4	4	4
2	LIVE NEWS CONFERENCE	-	105-2	4	4	4	4	4
3	IMISCIBLE LIQUIDS	102	109-3	3	3	2	3	3
6	FLUID MECHANICS	107	115-4	3	1	3	3	2
6	PLANT GROWTH	69	115-7	4	1	2	3	2
6	COMET SKETCHES	-	117-1	2	2	2	3	2
11	LIQUID FLOATING ZONE	101	129-6	3	1	2	2	1
13	PLANT GROWTH	69	136-4	3	1	2	2	1
14	LIQUID FLOATING ZONE	101	137-2	4	3	2	3	3
15	LIQUID FLOATING ZONE	101	140-1	4	3	2	3	3
15	LIQUID FLOATING ZONE	101	141-2	1	2	2	2	2
15	EARTH SURFACE	78	143-2	4	3	1	3	3
18	M509	36	150-2	3	2	1	3	3
18	FLUID MECHANICS	107	153-3	3	2	3	3	2
19	FLUID MECHANICS	107	154-2	3	2	2	3	2
21	M509	36	162-1	2	2	2	3	2
23	FLUID MECHANICS	107	168-4	2	1	1	3	2
24	EARTH SURFACE	78	174-1	2	3	1	3	2

APPENDIX E - (concluded)

DOY	SCENE TITLE	TV NO	DUMP NUMBER	NOISE DROP OUTS	CONTRAST	SPOTS AND BLEMISHES	SMEAR	RESOULTION & DEPTH OF FIELD
24	FLUID MECHANICS	107	174-3	2	2	1	3	3
25	LIQUID FILMS	103	178-1	1	2	2	3	2
25	LIQUID FILMS	103	178-3	3	4	1	3	4
26	EREP	11	184-1	2	2	2	3	3
27	GYROSCOPE	104	186-2	3	2	1	3	2
27	LBNP	6	187-2	3	2	1	3	2
31	AERODYNAMICS	84	198-1	2	3	2	3	3

APPENDIX F - PORTABLE CAMERA VIDEO LEVEL SUMMARY

DOY	DUMP NO	WINDOW AMP W/SYNC CONSTANT 40 IEEEU	SYNC AMP W/WINDOW CONSTANT 100 IEEEU	DOY	DUMP NO	WINDOW AMP W/SYNC CONSTANT 40 IEEEU	SYNC AMP W/WINDOW CONSTANT 100 IEEEU
147	5-1	100	40.0	225	41-2	115	34.8
149	9-11	70	57.1	226	42-1	135	29.6
150	10-5	100	40.0	227	40-1	120	33.3
151	13-2*	105	38.1	227	46-3	125	32.0
154	17-3	120	33.3	227	49-2*	110	36.4
154	19-4*	100	40.0	228	57-2	120	33.3
157	26-3*	105	38.1	229	58-1	125	32.0
157	26-4*	100	40.0	230	63-1	115	34.8
159	33-3	100	40.0	230	65-2*	105	38.1
160	36-1	115	34.8	230	68-2	115	34.8
163	41-3*	110	36.4	230	69-1*	120	33.3
164	46-2*	110	36.4	232	100-3	112	35.7
209	1-1*	109	36.7	233	75.5	132	30.3
209	1-3*	105	38.1	233	75.5	130	30.8
212	3-1	115	34.8	235	81-2	125	32.0
212	4-1*	105	38.1	236	88-1	120	33.3
212	5-3*	105	38.1	236	90-4	115	34.8
212	6-3	120	33.3	236	93-7	120	33.3
213	7-2*	110	36.4	236	96-1	125	32.0
214	8-3*	102	38.4	239	98-1*	120	33.3
214	9-3*	110	36.4	240	103-1	140	28.6
216	11-4*	105	38.1	240	102-7	140	28.6
216	12-3*	120	33.3	241	104-2	130	30.8
219	16-3	125	32.0	241	105-1	125	32.0
220	19-1	130	30.8	241	109-4	130	30.8
221	24-1	118	33.9	242	112-2	130	30.8
222	27-2	135	21.6	242	115-2	135	29.6
222	27-1	125	32.0	249	140-5	125	32.0
223	37-1	125	32.0	251	144-3	125	32.0

*INDICATES REAL TIME DUMP.

APPENDIX F - (continued)

DOY	DUMP NO	WINDOW AMP W/SYNC CONSTANT 40 IEEEU	SYNC AMP W/WINDOW CONSTANT 100 IEEEU
251	144-5	125	32.0
251	146-2	125	32.0
251	148-2	125	32.0
253	156-2	135	29.6
254	160-4	135	29.6
255	167-4	136	30.8
256	173-2	130	30.8
257	177-3	135	29.6
257	184-1	130	30.8
260	188-2	125	32.0
262	195-1*	120	33.3
262	195-1	130	30.8
263	198-4	120	33.3
263	205-3	135	29.6
321	1-1	105	38.1
321	1-1	75	53.3
321	1-2	105	38.1
323	2-2	110	36.4
325	21-1	120	33.3
329	4-2	105	38.1
330	4-3	120	33.3
330	4-4	120	33.3
331	9-9	105	38.1
333	14-1	117	34.2
333	14-3	115	34.8
335	21-3	115	34.8
335	23-1	117	34.2
336	24-2	115	34.8
337		115	34.8
338	28-2	118	34.2
339	32-2	123	32.5
340	35-2	123	32.5
340	37-3	120	33.3
341	41-3	113	35.4
342	41-6	120	33.3
346	54-5	118	34.2
348	60-1	110	36.4
349	63-1	110	36.4
350	65-2	116	34.5
352	69-1	104	38.5
354	73-1	120	33.3
356	77-3	120	33.3
358	83-2	115	34.8
362			
362	92-1	102	39.2
365	100-1	110	36.4
1	101-2	116	34.5
1	103-2*	108	37.0
2	104-3	112	35.7
2	104-7	108	37.0
2	104-7	111	36.0
2	104-7	111	36.0
2	105-2*	108	37.0
3	109-3	111	
6	115-4	110	36.4
6	115-7	110	36.4
6	117-1	112	35.7
11	129-6	112	35.7

APPENDIX F - (continued)

DOY	DUMP NO	WINDOW AMP W/SYNC CONSTANT 40 IEEEU	SYNC AMP W/WINDOW CONSTANT 100 IEEEU	DOY	DUMP NO	WINDOW AMP W/SYNC CONSTANT 40 IEEU	SYNC AMP W/WINDOW CONSTANT 100 IEEEU
13	136-4	115	34.8	23	168-4	112	35.7
14	137-2	115	34.8	24	174-1	115	34.8
15	140-1	112	35.7	24	174-3	115	34.8
15	141-2*	108	37.0	25	178-1	115	34.8
15	143-2*	108	37.0	25	178-3	125	32.0
18	150-2	110	36.4	26	184-1	118	34.2
18	153-3	72	55.6	27	186-2	120	33.3
19	154-2	112	35.7	27	187-2*	118	34.2
21	162-1	110	36.4	31	198-1*	115	34.8

NASA TMX-64819

APPROVAL

MSFC SKYLAB INSTRUMENTATION AND COMMUNICATION SYSTEM MISSION EVALUATION

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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